

Analysis of a Martial Arts Front Kick

Alex Weintraub

Advisor: Dr. Andrew Rapoff

Study Design: A motion and force analysis of a martial arts front kick

Objectives: To quantitatively and qualitatively analyze a martial arts front kick to determine how to deliver the maximum impact force of a kick

Summary of Background Data: Different styles of martial arts will all teach a front kick different ways. For the most part these kicks are all very similar, but there are slight changes from style to style that could prove to be a large factor in the kick. Similar analyses have been done on this kick as well as other types of kicks.

Methods: I filmed myself with a digital camera doing a number of front kicks, slightly varying some of the variables in the process. To quantitatively analyze the kicks I took one of the kicking clips and with it found position, velocity, and acceleration values using the Videopoint program. With these values I then attempted to use relative motion equations to calculate the position, velocity, and acceleration of the hip, knee, and ankle joint, as well as the point of impact on my foot. To qualitatively analyze the kicks I looked at clips of slightly altered kicks to see which kick resulted in the greatest resultant force.

Results: The relative motion analysis ended up not working out due to the fact that the equation matrix came out to be undefined. From the qualitative analysis I found that the kick would result in the highest force when the kick is delivered at hip height, with the knee completely

extended, and the ankle bent at a 45° angle.

Additionally the knee does not begin to extend until the leg is raised to the hip height.

Conclusions: To quantitatively analyze the kick, either a more complicated set a relative motion equations is needed, or a different approach all together is needed. The qualitative analysis showed expected results. The way that I have been taught, and teach to others how to do the kick is the way that delivers the highest force on impact.

The front kick is one of the simplest and also most commonly used kicks in the martial arts. The front kick is performed by raising the leg to hip height and then snapping out your knee and hitting with the ball of your foot. Also note that the toes are pointed up away from the ball of the foot so that they don not interfere with the point of impact. To bring the foot down the motion is carried out in reverse.

Although for the most part how the front kick is performed is rather standard, there are variations in the kick from martial art style to style. I have trained for 15 years and taught for 5 years in the art of Jujitsu and during this time I have performed and taught this

kick thousands of times. At this point I would consider myself an expert on this kick, yet still feel that I can improve on the form of my kick. This project has been undertaken so that I can figure out the precise way to kick to allow for the maximum impact force. This primary objective is of interest to me so that I can actually test and figure out which is the best way to do a front kick. Up until this point I have only been told and read about how the kick is performed, so this project will allow me to prove how the kick should be performed. In this project I will analyze video data to figure out my primary objective of how to kick to allow for the greatest impact force.

■ Methods

Filming

To start off the project I had to first get video data that I would be able to analyze. To do this I was able to use a digital video camera to film myself doing several front kicks. When filming I wore form fitting clothing and marked off six points on my leg with small pieces of duct tape. Two points were marked off on my upper leg, lower leg, and my foot which would later allow me to calculate the motion of my leg at these

points using the Videopoint program. In addition to the markers on my leg I also marked off a section of wall behind me which was 0.3 meter in length and would allow for me to scale the movie in Videopoint. With this setup I went through a number of different kicks slightly altering each kick so that later I would be able to qualitatively analyze these different kicks. While altering the kicks I altered the height of the kick, angle of my ankle, and at what point did I begin to extend my knee. I kept kicking until I had several kicks that I could use for my different analyses. With this data I could then move onto the next step of getting the data into a form where I could use it for analysis.

Videopoint Analysis

After importing the video data into the computer I was then able to carry out the analysis in Videopoint. I first had to set up several points of analysis and scale the movie. I had to define the points of interest for the program to analyze, and did this by following the markers that I had placed on my leg over forty-two frames of the movie clip. Each frame was separated by 0.03333 seconds and the entire clip occurred over 1.368 seconds. The initial

frame with the points marked off on my leg and scaled distance can be seen in the initial frame as **Figure 1** in Attachment A. After each of these points was defined, the motion of my leg could then be analyzed by the program for position, velocity, and acceleration both linear and angular at nearly every point. Additionally to allow for this analysis I used the length of 0.3 meter to scale the movie. With all of these points defined and the movie scaled the analysis could be carried out, and the values found for points 1 through 6 can be seen in Tables 1-6 in Attachment B.

■ Results

Quantitative Analysis

The first analysis to be carried out was a relative motion analysis, which would utilize the values found from Videopoint along with relative motion analysis to calculate the values of other important points such as the hip, knee, and ankle joints, as well as the point of impact. A system of equations was initially setup to be used to solve for the position, velocity, and acceleration values of other points of interest on the leg. These equations can be seen in Attachment C. As briefly mentioned earlier, and as seen in the relative motion

analysis these equations did not end up working out due to the fact that for the set of equations in the x direction the matrix being used to solve the equations came out to be undefined. This undefined matrix made it so these equations could not be used to solve for any other points of interest found, and another more complicated approach would need to be used to solve for the points that I was interested in.

Qualitative Analysis

After much deliberation and calculation I was able to come to the conclusion that the set of equations that I was attempting use was not going to work. I additionally attempted to work from example problems, but this resulted in nothing significant as well, so I decided that it would be best to do a qualitative analysis. With my knowledge on the kick I would still be able to come to some very reasonable conclusions with this data.

As mentioned earlier for this analysis I was looking at several different types of front kicks that had slightly altered variables to see which resulted in the greatest impact force. From looking at these video clips the following results became apparent.

When kicking the greatest amount of force was generated when the kick was being performed at hip height. As the kick went higher from this point, force was sacrificed for height, and if the kick was any lower than this point there was too short of a distance to generate any force. It was also to best have the ankle bent at a 45° angle. With the ankle bent at this angle it allowed for the ball of the foot, the impact point, to be parallel with the target it was hitting, which was ideal. Finally the third variable taken into account was when to start bending your knee while kicking. From this it was found that the most force generated would be when the knee is first fully raised to hip height and then the rest of the leg is extended to perform the kick.

Although this qualitative analysis was not the most precise, it still was very useful given all of my previous knowledge along with the ability to view it frame by frame on video.

■ Discussion

Issues with the Relative Motion Equations

The relative motion equations not working was a major problem I encountered in my analysis. From the start of my project the plan was to gather

the Videopoint data, and then use the relative motion equations to solve for the other points on my leg I was interested in. I put a lot of time into figuring out these equations, and then trying to fix these equations, so having them not work in the end was an issue.

The reason I believe that the equations did not work was most likely because of the fact that the equations might have been dependent on one another. Because of this reason one of the matrices came out to be undefined. It may have been possible to solve the system of equations I had, but I would need to introduce more equations because of the dependency issue that I had. Having these equations not work out was detrimental to my project in several ways because not only was it the way I was planning to analyze my kick, but I also poured a great deal of my time into attempting to figure these equations out.

If at some point I am able to I will go back and take another look at the equations that I had come up with. It may be possible that a more complex relative motion analysis might work, or I may have to try a totally different approach all together, but either way

there is some way that I should be able to solve the problem that I have presented myself with.

Validity of Results

Although the initial quantitative analysis that I planned on doing from the start did not work out, I was still able to do a qualitative analysis on my kicking given video data, and my background knowledge of this kick. From this data I got results that I expected.

Similar concepts that I have always applied proved to be the way to perform the kick with the most impact force. If one is strictly looking to get the most force out of a kick the best height to kick at is hip height. This makes sense because at this point the impact point of the kick will be flat to the kicker. If the target is higher or lower an angle will become involved in the impact point, which will make it more difficult to deliver a kick of equal impact force. Additionally with the ankle bent at 45° the ball of the foot becomes flat to the target, which again for the same reason explained above allows for the greatest impact force. Finally by completely bringing one's knee up before beginning to move the lower portion of the leg allows for the greatest

impact force because this way there is no swinging motion due to the continued motion of the hip. This swinging motion makes it harder for the kick to have its force directed straight out. By waiting to move the lower portion of the leg more force is able to be generated out toward the target, instead of taking more energy to move one's leg up as the entire leg is attempted to move together.

It is also important to note that this way of performing a kick only yields the greatest impact force, and not a different type of result. If one is looking to have the highest or fastest kick the kick will be done differently, and that is another project all together.

I was pleased with the results that came out of this qualitative analysis. Looking at my kick frame by frame at such a slow pace allowed for me to truly break it down and analyze it down to the minutest detail.

Acknowledgements

I would like to thank Dr. Andrew Rapoff for advising me through this entire process, and helping a great deal a long the way. I would also like to thank Stan Gorski for all of his technical assistance with the filming and format conversion. Finally I would also like to

thank Union College for the use of both
their equipment and facilities.

List of Attachments

Attachment A – Videopoint Setup

Attachment B – Videopoint Data

Attachment C – Relative Motion

Equations

Attachment A – Videopoint Setup

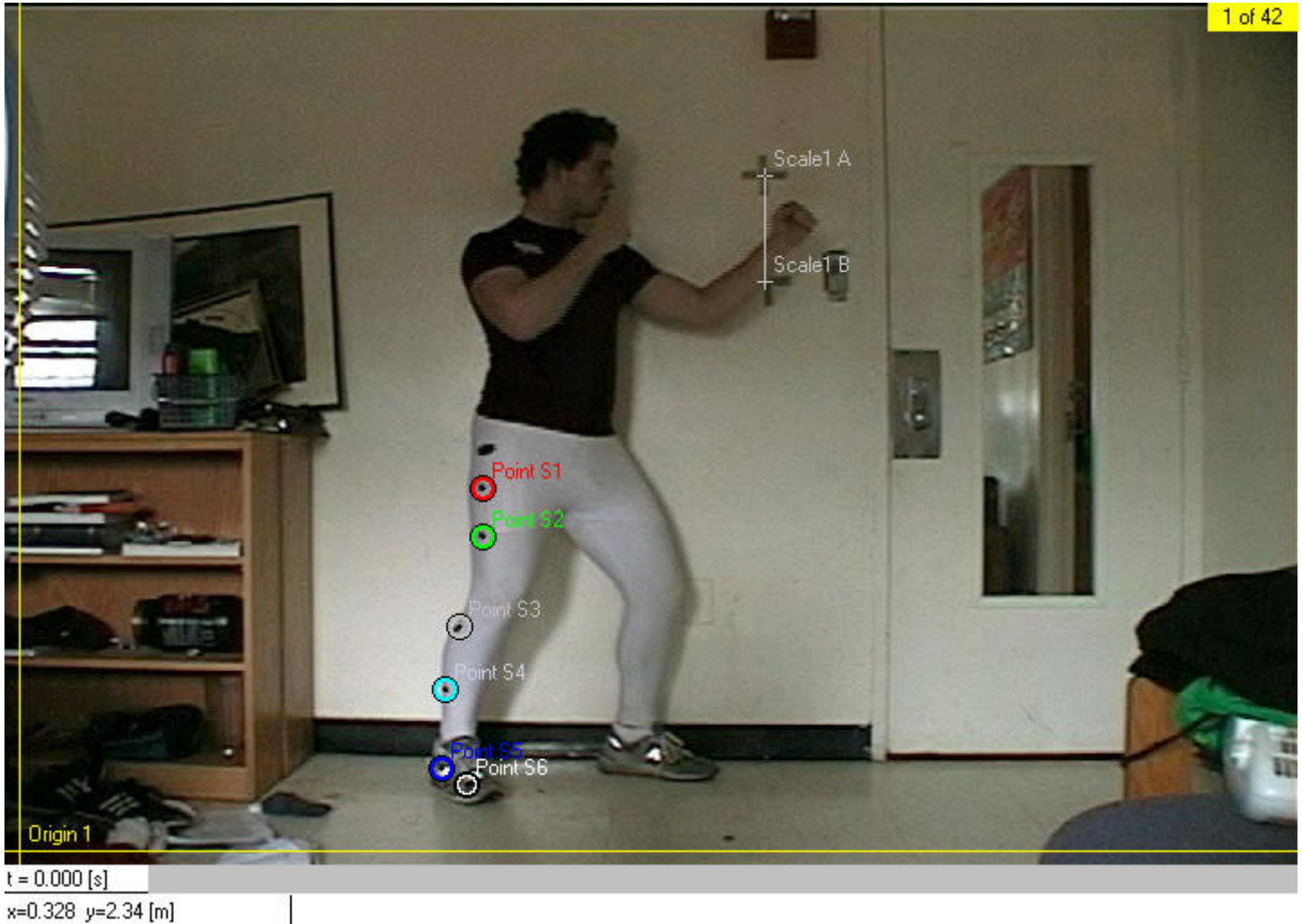


Figure 1 – An image of the first frame in the video clip with the 6 points of interest marked off, as well as the scaling done as seen by the marked off distance on the wall.