Weight and Strength Dependency in Cheerleading Stunts

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Cheerleading is one of the most dangerous sports for young women and produces the highest rate of catastrophic injuries in female athletes. Because of the increased difficulty in stunts over the last fifteen years, the rate of cheerleading injuries has significantly increased. Often, the bases of the stunts are the ones who are injured. In this study, the dismounts from prep or elevator level stunts were tested in relation to the strength of the stunt group and the weight of the flyer. A group of collegiate cheerleaders participated in performance tests to gauge their strength. Seven combinations of stunt groups and flyers performing elevator level stunts were video recorded. The dismounts from the stunts were tracked and then analyzed based off of the flight of the flyer. From this data, it was concluded that increasing the mass of the flyer decreases her acceleration into the air. Additionally, it was concluded that a stronger stunt group retains more consistent results during the entire study. Therefore, it was concluded a strong stunt group is essential for consistent stunts, however a lighter flyer will result in a perceived faster stunt sequence.

I. INTRODUCTION

Cheerleading is one of the fastest growing sports in the country and is statistically has the highest rate of injuries for female athletes. Though once an activity primarily consisting of men and women cheering on a sports team, it has evolved into a competitive sport for participants as young as the age of five [1]. In three decades, the sport has evolved from basic maneuvers, such as toe-touches and cheers, to tumbling, pyramid stunts, partner stunting and high flying basket tosses [2]. Due to the increase in difficulties of these stunt maneuvers the rate of cheerleading related injuries has drastically increased 110% over a thirteen year period [2]. Cheerleading also represents a disproportionate number of catastrophic injuries, as it accounts for over 50% of all hospital reported injuries for female sports participants [3].

There is a limited amount of accurate research regarding the frequency of injuries and pervasive injuries in cheerleading primarily because cheerleading is not recognized as a sport by the NCAA and many other major sport organizations [1]. This is shown in the lack of injury reporting except in the cases of those requiring hospital care [3]. Even though it has been proven that cheerleading requires the same physical fitness as other recognized sports, cheerleading is still not considered a sport my most major sports organizations [1].

Stunt related injuries account for 60% of all cheerleading injuries [2]. Because stunting is the primary focus of high school, collegiate and All-Star (competitive) cheerleading, it is important to understand the cause of injury. Ankle injuries are the primary injury affecting cheerleaders [3]. Though one may suspect the flyer, the cheerleader who is elevated by the bases, may sustain the majority of the injuries, the most common mechanism of injury is from basing or spotting a stunt [1]. However, falls (often sustained by the flyer) are most likely to be catastrophic [1]. Most injuries cause cheerleaders to lose a least one day of practice or performance [2].

There are several reasons why there is an alarmingly high rate of cheerleading injuries throughout all ages and levels. Participants have high demands on their musculoskelatal systems with close interactions during stunting with participants who have the same strain on their bodies [1]. Landing mechanisms of these athletes may be a cause to injuries, due to the energy and force placed on the athlete [1]. Additionally, because cheerleaders cheer at multiple sporting events throughout the year the season is often two times longer than other sports [3]. One of the most prevalent recommendations from cheerleading injury studies which focus on the rates of cheerleading injuries is that cheerleaders should participate in a strength conditioning routine. Because bases and spotters are the main participants to be injured, it is important they are properly trained for the stress on the body. Therefore, it is important to understand the strength dependency of the bases in a stunt compared to the weight and force from the flyer.

II. THEORY

The dismount from a cheerleading stunt requires the proper combination of force and momentum based on the mass of the flyer. This begins with the flyer, who equally balances her weight on both legs, shown in Fig. 1. Each foot is held by a side base and each ankle is held by the back spot. The foot is supported by the side base so her fingers wrap around the heel and toes of the foot and the palms of the hands meet in the middle. Therefore, the majority of the weight on each leg is held by the palms of the hand by the side bases. The back spot provides support by pulling up on the back of the flyer's ankles, relieving weight from the side bases.

The stunt is driven by the force of the stunt group holding up the flyer. Fig. 2 shows the different elements of the dismount. During the entire stunt the flyer keeps her body as still as possible, until the cradle at the end. When the stunt begins the flyer is at rest and the flyer held by the stunt group, shown in Fig. 1. The force of the

FIG. 1: An example of a prep level stunt. A flyer is supported by a base on each side and a back spot who supports both legs of the flyer [4].

bases F_B is equal to the weight of the flyer, $W_F = m_F g$. When the dismount begins the synchronized bases and back spot push the flyer into the air to gain momentum. Therefore $F_B > W_F$. The stunt group then slightly lowers the flyer to prepare for the final push into the air, where $F_B < W_F$. Up to this point, the flyer's feet are still in the hands of the bases. During the final push, the bases launch the flyer $F_B >> W_F$ and lets go of her feet. This flyer travels upwards until $V = 0$. At this point, the flyer drops her tailbone into a sitting position and falls at an acceleration of g to the bases below her. The flyer is cradled by the three members of the stunt group.

III. PROCEDURE

For this study, seven collegiate cheerleaders were selected to participate. The group consisted of six of female and one male participant . All of the cheerleaders had cheered for at least one or more cheerleading seasons and had been trained in stunting. Each cheerleader wore the same type of shoes and dark colored, light weight clothing. Each flyer wore a piece of tape around her waist and hips for tracking, as shown in Fig. 3. Each of the cheerleaders' height and weight was taken in the same shoes and clothes they wore for the study.

TABLE I: Strength, Mass and BMI of Participants

Strength Ranking	Cheerleader	Mass (kg)	BMI	Type
1	D	71.4	23.3	Back
2	F	57.0	19.6	Flyer
3	E	59.4	19.6	Back/Flyer
4	B	63.0	22.8	Base
5	A	78.5	27.2	Base
6	G	45.3	17.7	Flyer
7	C	68.6	22.7	Back

TABLE II: Stunt Group Strength and Cheerleader Combinations

Strength Ranking	Stunt Group	Flyer	Back	Strength Value
1	Gamma	F	D	157
2	Zeta	E	D	156
3	Alpha	G	D	141
4	Delta	G	E	107
5	Epsilon	F	C	102
6	Beta	E	C	101
7	Eta	G	C	86

Next, a performance test was conducted for each participant. These performance tests were used to gauge the strength of the participants' in the arms, legs and core. Each participant completed the maximum number of push ups they could in one minute, the maximum number of sit ups they could in one minute and a hop test. These performance tests have been proven to accurately reflect the strength among both men and women [5]. The push up and sit-up test were used to gauge overall core and arm strength. The results from the performance tests, as well as the individual height and weight are located in Table I. The strength results were calculated as the sum of the sit-ups and push ups an individual could do during the performances tests. In this table the participants are ranked based on their strength performance tests. A low ranking reflects the strongest participant in the group. However, a high number for the strength value reflects a strong stunt group.

Next, the stunt groups were determined. This can be found in Table II. These stunt groups were ranked based off their strength, with the strongest groups having the lowest rank and the highest strength values. The stunt group strength value was based on the total number of sit-ups and push-ups performed by the members of the stunt group. To avoid confusion with stunt group rankings, the stunt groups are referred to with Greek letters.

During the study the two side bases were constant

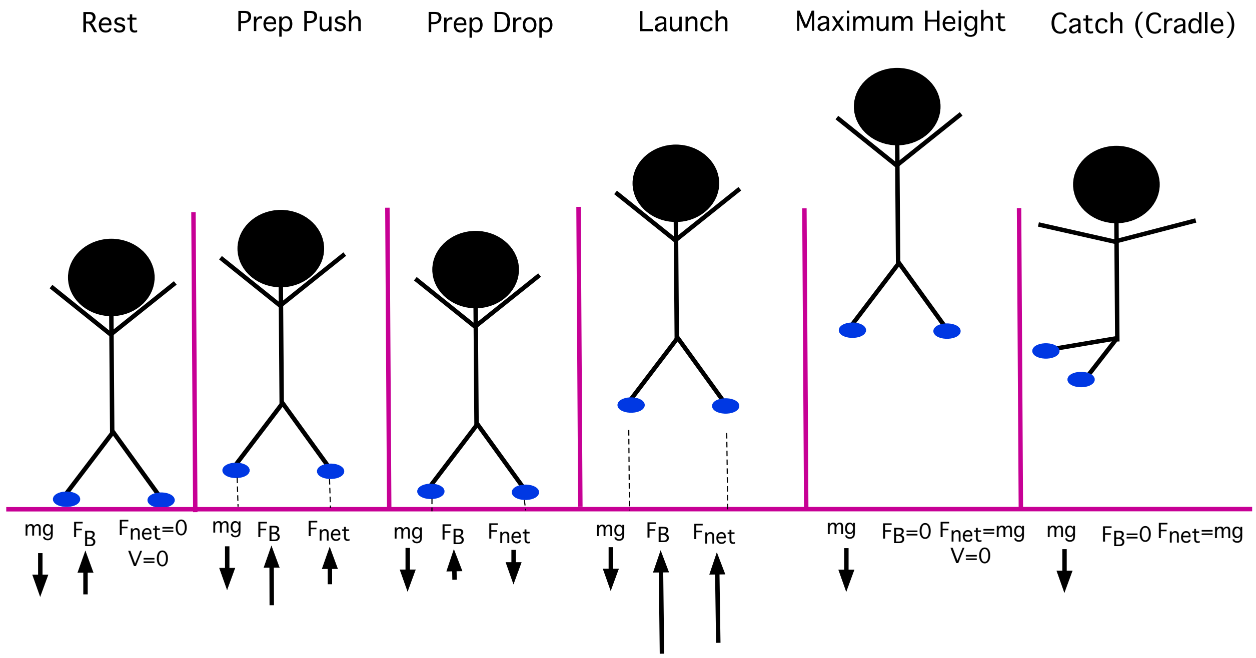

FIG. 2: This diagram shows the flight of the flyer in a stunt. The flyer starts at rest. The bases and back give her an initial push, drop her slightly and then launch her into the air. The flyer reaches her maximum height when velocity her velocity is zero and then she falls until she is cradled in the arms of the bases and back.

FIG. 3: This figure shows a flyer with the pieces of tape around her natural waist and hips. The waist tape was used to measure the flight of the flyer in each stunt.

through all trials of the stunt groups. The back spot and flyer was changed for each stunt. The stunt was loaded in at the call of the back spot and then held at the starting position, as shown in Fig. 1. In this position, the weight of the flyer is equally distributed between the two bases and the back spot. On the call of the back spot, the flyer is launched into the air using an initial push, drop and launch into the air, as described previously. The flyer is then cradled by the three bases. This routine was performed in two trials by each stunt group. The stunt was captured by two digital video cameras, one which captured the stunt head-on and another at a 90° angle in relation to the front of the stunt. To allow to optimal anaerobic recovery time for the stunt group, there was a wait time of three minutes between each stunt [6]. For the analysis, each stunt video was analyzed by tracking the position of the band around the waist and hips frame by frame.

IV. RESULTS AND ANALYSIS

Based on the tracking positions of the flyer, two different factors were studied in relation to the strength of the stunt group and the weight of the flyer. The peak velocity of the stunt was recorded for each trial. Additionally, the acceleration of the final push of the stunt was recorded. In Fig. 4 the actual path of the stunt is tracked as the maximum velocity versus time. The peak velocity was found in the second peak in the graph, where the flyer reached a maximum velocity in the air, before eventually falling to a cradle. The slope of the second velocity rise represents the acceleration of the flyer during the final push into the air. Table III shows each trial's peak velocity and acceleration into the air after the push. Included in this table is the strength rank, strength value, flyer and back combination, along with the weight of the flyer. This is shown for the two trials recorded of each stunt group.

Using the data in Table III there are many ways in which the data can be analyzed. First, we can explore

TABLE III: Stunt Group Trial Results

Ranking	Stunt Group	Mass of Flyer(kg)	Strength Value	Trial	Peak Velocity(cm/s)	Acceleration(cm/s^2)
1	Gamma	57.06	157	1	115	848±60
				2	108	816±49
2	Zeta	59.4	156	1	123	827± 41
				2	161	829±41
3	Alpha	45.3	141	1	114	983±48
				2	113	990±28
4	Delta	45.3	107	1	102	951± 88
				2	116	822±53
5	Epsilon	57.0	102	1	104	738±45
				2	150	741±22
6	Beta	59.4	101	1	114	686±34
				2	106	929±34
7	Eta	45.3	86	1	107	844±70
				2	116	1038±51

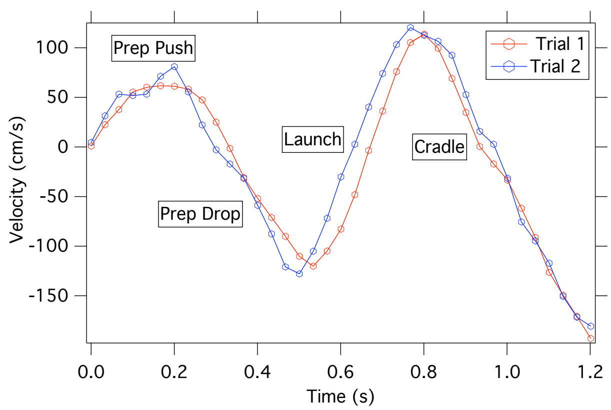

FIG. 4: Graph of velocity of the flyer as a function of time. The graph shows the initial push of the flyer, the initial drop and then the launch into the air. The peak velocity is reached and then the flyer falls down in the cradle.

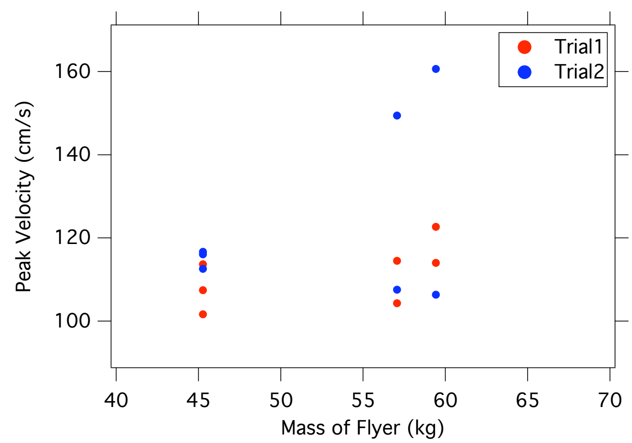

FIG. 5: The relationship between the maximum velocity of the stunt and the mass of the flyer. The data shows a trend that regardless of the mass of the flyer, the maximum velocity of each stunt is very similar. There are two outliers in this graph, which represent a non consistent push during the dismount from the stunt group.

the relationship between the maximum velocity and the factors of the stunt including the mass of the flyer and the strength of the stunt group. In Fig. 5, the relationship between the mass of the flyer and her peak velocity is graphed. It can be concluded that regardless of the mass of the flyer, in general, the peak velocity is similar across stunt groups. Similar results are found in Fig. 6, which shows the velocity as a function of the strength of the stunt group. This graph shows the peak velocity, but as a function of strength of the stunt group. Again, a general pattern can be observed that regardless of the strength of the stunt group the peak velocity of the flyers are similar. From this data we can conclude the peak velocity does not vary in the relationship between strength of a stunt group and the weight of the flyer.

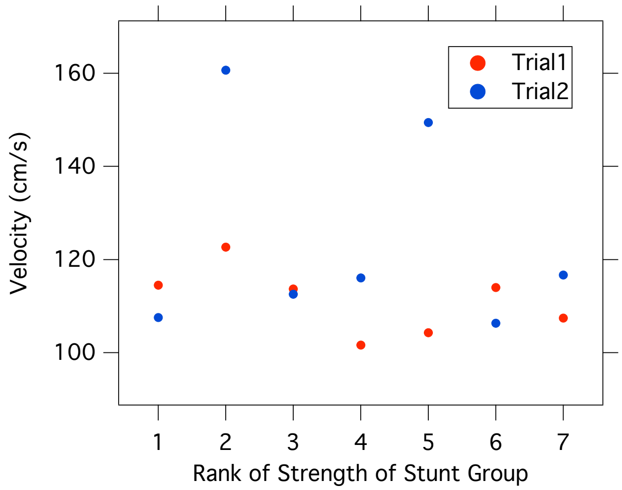

FIG. 6: The relationship between the strength of the stunt group and the maximum velocity. Once again, we see a trend that despite the strength of the group, the maximum velocity is similar for all trials.

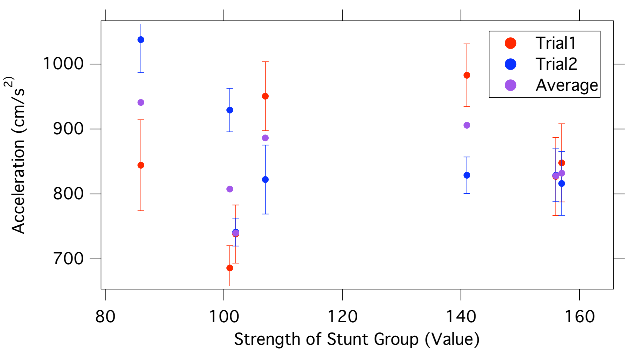

FIG. 7: The relationship between the strength of the stunt group and the acceleration of the flyer. The strongest stunt groups are represented on the right side, with the larger numbers. We can note as the stunt group decreases in strength the consistency of the stunt also decreases between trial.

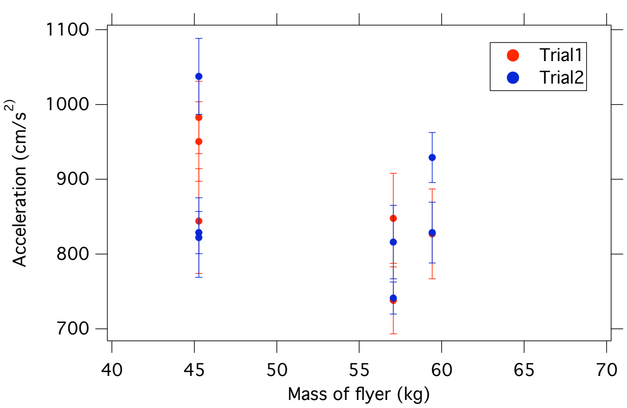

FIG. 8: The relationship between the mass of the flyer and the average acceleration. We can conclude that with a less massive flyer the stunt can be executed with a faster acceleration and therefore have a faster dismount.

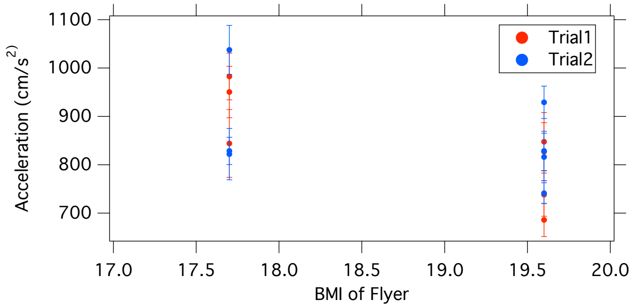

FIG. 9: The relationship between acceleration of the flyer and the BMI (Body Mass Index) of the flyer. Two of the flyers have the same BMI. We can conclude that a flyer with a smaller BMI can be executed a stunt with a faster accelerationtand therefore a faster dismount.

Additionally, the average acceleration of the stunt was tracked during the final launch of the stunt. First, this was graphed as a function of the stunt group strength, which can be found in Fig. 7. These results include the two trials of the stunt, along with the average acceleration between the two trials. A higher strength value represents a stronger stunt group. The data implies that stronger stunt groups result in more constant results, compared to weaker stunt groups, which have a larger variation in the data. However, these data are not conclusive and would show better results with an increase of trials.

The most important comparison in data is the acceleration in relation to the mass and BMI of the flyer. In Fig. 8, the relationship between the acceleration and the mass of the flyer is shown. In this graph, we see that a less massive flyer has a greater acceleration. Therefore, we can conclude that a stunt can be executed faster with a less massive flyer, regardless of the strength of the group. Fig. 9 produces similar results. This graph shows the relationship between the acceleration and the BMI, Body Mass Index, of the flyer. Two of the three flyers in the study have the same BMI. Once again we can conclude a flyer with a lower BMI results in a larger acceleration and therefore a quicker stunt. This is because a faster acceleration is perceived as a faster stunt. Therefore, if a cheerleading squad wants a fast paced stunt sequence, it is ideal to have the lightest flyers in the stunt, despite the strength of the stunt groups.

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