A Pilot Study of Deflection of a Cerebral Palsy Therapy Unit

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MeSH Terms

- cerebral palsy
- exercise therapy
- data interpretation
- statistical analysis

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OBJECTIVE. Our objective was to determine how much the mesh of the spider cage deflected at each carabiner connection point during a slip test. The results will help determine where the safest attachment points on the cage will be and provide a recommended setup for therapists using the spider cage for therapy.
METHOD. Five participants performed a slip test with three different setup locations and sixteen carabiner attachment points to the mesh of the cage. We used a dial indicator to measure the mesh deflections of eight out of the sixteen carabiners and assumed symmetry during the slip test. We ran statistical analyses on the results to determine if there was a significant difference in deflection at each carabiner attachment point between the three test setups.
RESULTS. For test subjects 1, 2, and 3 there was a significant difference in deflection between the three test setups for three of eight tested carabiner locations. For test subjects 4 and 5 there was a significant difference in deflection between the three test setups for seven of the eight carabiner locations. The test setups that had carabiner attachment points closer to the sides of the cage deflected less than those farther away from the sides.
CONCLUSION. The mesh closer to the beams of the cage are the safest areas for carabiner attachment as they deflect the least.

Cerebral palsy affects 17 million people worldwide [1] and 764,000 of those individuals are from the United States [2]. The incidence of cerebral palsy in children is 3.1 in 1000 across the United States, and 2.6 in 1000 in Wisconsin [3]. Different therapies and treatment techniques are being developed to aid those with the disability.

Cerebral palsy is a group of non-progressive, non-contagious motor conditions caused by a delay in physical development. Almost 80% of cases are acquired prenatally and arise from abnormal brain development of the fetus. Premature and low birth weight babies are most at risk for developing cerebral palsy and the disease affects 0.2 - 0.35% of all live births [4]. Perinatal and postnatal causes each account for 10% of cerebral palsy cases and are caused by infection and head trauma [5]. The disorder affects each individual differently and can cause complications in one limb, two limbs, or even the whole body. The two most common forms of cerebral palsy are ataxia, which is defined as a lack of motor control with voluntary movements, and spasticity, which is categorized as stiff or tight muscles and exaggerated reflexes [6]. Aside from interfering with physical movement of the body, cerebral palsy can also cause disturbances in sensation, perception, communication, and behavior. Currently there is no cure for the disorder but there are treatment options to help make the lives of those affected as independent and manageable as possible.

Forms of treatment for cerebral palsy include surgery, medication, and therapy. Surgery can be performed to release tight muscles and to correct anatomical abnormalities, leading to reduced pain. Medications can be taken to control spasticity, seizures, and to reduce pain. Physical therapy is another, less invasive, treatment option. The goal of therapy is to help individuals gain bodily function by helping them learn to control gross motor functions. Therapy equipment includes, but is not limited to, resistant bands, orthotics, and an exercise unit called a spider cage [6].

The notion of spider cage therapy was first introduced in Poland by Norman Lozinski in 1994. The therapy is set up by attaching a set of resistance bands to a customized suit worn by a patient as well as attaching the resistant bands to the mesh cage of the structure. The bands may have varying stiffness depending on the needs of the patient and the specific exercises performed. The goal of spider cage therapy is to help patients improve balance, gain muscle strength, and develop coordination [7]. Ideally, the therapy will help the patient learn/build skills to perform daily tasks and gain independence.

In this study we built a spider cage out of 80/20 aluminum and tested the deflection at eight different carabiner attachment points over three different test setups. The goal of the experiment was to determine if there was a significant difference in deflection between the three test setups at each carabiner location. A slip test was simulated as a worst case scenario as this would be the cause of the greatest possible amount of deflection on the mesh during therapy use. Our hypothesis was that there will be a significant difference in the deflection of the mesh between the three test setups.

Method

Research design

The five authors of this paper performed a slip test within the cage to determine the functionality as well as the structural stability of the cage. The exercise for the experiment consisted of performing a slip test while supported by the cage via a harness and eight resistance bands. There were two test groups based on weight and each group had three distinct test setups. A test procedure and carabiner attachments for each test setup can be found in Appendices A and B respectively. The deflection information can be used to recommend which carabiner attachment locations are safest for therapy use as they will be the ones that deflect the least.

Participants

Five participants with weights ranging from approximately 100 to 200 lbs and heights ranging from approximately 5 to 6 feet completed the slip test. Details on each individual can be found in

Table 1. The authors have a large range of weights and heights, which are representative of the patients that will be using the cage.

Table 1: A list of the five study participants' heights and weights.

Name	Height	Weight (lbs)
Subject 1	5' 3"	128
Subject 2	5' 6"	130
Subject 3	5' 7"	135
Subject 4	6' 1"	195
Subject 5	6' 3"	194

Instruments

Dial indicators measure small amounts of deflection with a higher precision than other methods such as using a measuring tape or observing deflection with the naked eye. The amount of deflection of the cage was difficult to observe because it was so slight, therefore, the dial indicator was used to precisely measure the deflection of the mesh. The dial indicator used had a resolution on the scale of one thousandths of an inch.

Data collection

The mesh deflection data was collected at each carabiner location using a dial indicator. Cardboard squares were attached as close as possible to the carabiner attachment points on the mesh and the tip of the dial indicator was flush against the cardboard for the start of each slip test then was compressed a certain distance when the mesh deflected. Three videos of the dial indicator readings were recorded at each carabiner location during the slip tests and the videos were played back to collect the deflection values. The values at each location were averaged so that each test setup yielded eight measured deflection values, which then translated to sixteen deflection values after assuming symmetry of the cage.

Statistical Analysis

The participants were grouped based on weight and the groups were given separate setup conditions for support. Group one consisted of subjects 4 and 5 and group two consisted of subjects 1, 2, and 3. Both subjects in group one had the same three test setup locations which differed from the three setup locations of group two. The data collected from the two subjects in group one were analyzed together and the data collected from the three subjects in group two were analyzed together.

A one-way ANOVA test was used to provide a statistical analysis for the mesh deflection. The purpose of the analysis was to determine if the deflection at each carabiner location was significantly different between the three test setups. The ANOVA test was carried out using R which is a software program specifically used for statistical analyses. For each data set, the null hypothesis states that there will be no significant change in the deflections of the mesh at each carabiner location between the three test setups. The alternate hypothesis states the opposite: there will be a significant change in the deflections of the mesh at each carabiner location between the three test setups. A p-value was calculated for each data set and compared to a 95% confidence interval with an alpha value of 0.05. If the p-value was less than 0.05 then the null was rejected meaning that there was a significant difference between the deflections at each carabiner location for the three test setups. However, if the p-value was greater than 0.05, the null fails to be rejected concluding that there is no significant difference between experimental means [9].

Results

The deflection data collected from the dial indicators was averaged at each carabiner location for the three test setups and a visual of the deflections for each subject can be seen in Appendix C. A one-way ANOVA was used to determine if deflection at each carabiner location varied significantly between the three test setups and the results can be viewed in Table 2. Red text is used to represent p-values less than 0.05 and blue text is used to represent p-values greater than 0.05.

Table 2: Group one ANOVA p-values for variation in each test setup (top). Group two ANOVA p-values for variation in each test setup (bottom). Red text signifies p-values less than 0.05, blue text signifies p-values greater than 0.05.

Location	Carabiner 1	Carabiner 2	Carabiner 3	Carabiner 4	Carabiner 5	Carabiner 6	Carabiner 7	Carabiner 8
P-value	0.000263	0.000225	0.00155	0.0071	0.000422	0.001	0.0932	0.00126

Location	Carabiner 1	Carabiner 2	Carabiner 3	Carabiner 4	Carabiner 5	Carabiner 6	Carabiner 7	Carabiner 8
P-value	0.0752	0.285	0.0231	0.0161	0.0687	0.14	0.0928	0.0156

Discussion

The results from the deflection tests indicated that the greatest mesh deflection recorded was approximately 0.1 inches. An earlier test indicated that permanent deformation of the mesh occurred when the mesh experienced a deflection of 1.25 inches. All of the deflections from the slip test were much lower than this value and therefore we are unconcerned about the mesh of the cage experiencing permanent deformation when in use. However, the statistical analysis does indicate that there is a significant difference between some of the test setups at certain carabiner locations.

The one-way ANOVA for group one indicates that there was a significant difference in the amount of deflection experienced by each carabiner at the three test setups locations except for carabiner 7. Carabiners 7 and 8 experienced a lower amount of deflection than the rest of the carabiners and this could have caused the data to not vary as much as the other carabiner data between test setups. The deflection was lowest for test setup 1 when the carabiners were attached closest to the aluminum frame of the cage and highest for test setup 3 when the carabiners were attached farthest from the aluminum frame of the cage.

The one-way ANOVA for group two shows a significant difference in deflection between the test setups for carabiners 3, 4, and 8 and no significant difference for carabiners 1, 2, 5, 6, and 7. Group two experienced a deflection trend similar to that of group 1. The least amount of mesh deflection was seen at test setup 1 when the carabiners were closest to the frame of the cage and the greatest amount of deflection was seen at test setup 3 when the carabiners were farthest from the aluminum frame of the cage.

Implications

Our results imply that attaching the carabiners to locations closer to the edges of the cage causes the least amount of deflection. Although the other test locations did not experience a concerning amount of deflection, we suggest that therapists using the cage connect the carabiners closer to the edges for as safe a connection as possible. Patients with a variety of weights will be able to have their weight fully supported by the cage without any damage to the structure or concern for their safety.

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Appendix

A. Testing Protocol

Slip Test Mesh Deflection Procedure

Purpose: Setup and perform a slip test to view and measure deflection experienced by the cage. The purpose of the slip test is to determine if changing the carabiner attachment locations on the mesh will cause a significant difference in deflection of the mesh at the attachment points. The experiment will be conducted for five subjects with deflection measurements taken at three different attachment point setups and three tests at each attachment location. Group one will consist of the 194-195 lbs. subjects and will have different setup locations than group two with the 128-135 lbs. subjects.

Materials:

- spider cage
- harness
- resistance bands with carabiners
  - four 40 lbs. resistance bands and four 50 lbs. resistance bands
- dial indicator
- dial indicator stand/clamp
- video recording device
- plywood or any sturdy, flat surface
- 5 test subjects

Procedure:

1. Record height and weight of subject
2. Set up resistance bands at test setup 1
3. Have subject put on harness and tighten correctly
4. Setup dial indicator to measure deflection of the carabiner at attachment point #1
5. Have subject fall forward to imitate "slip" and record deflection measurement
6. Repeat step 5 for a total of 3 times
7. Change location of the dial indicator to the next carabiner and repeat steps 5-6
8. Repeat steps 4-7 for all carabiner locations with 3 dial indicator readings at each location
9. Repeat steps 4-8 for the other 3 test setups
10. Repeat steps 1-10 for all subjects

Note: Test setup document will indicate where to attach resistance bands. Attachment locations differ between group one and group two.

B. Test Setups

Image of test setup for group 1: back panel (left) and top panel (right) with test setup 1 in green, 2 in orange, and 3 in red. Assume symmetry for top panel (same setup on opposite side).

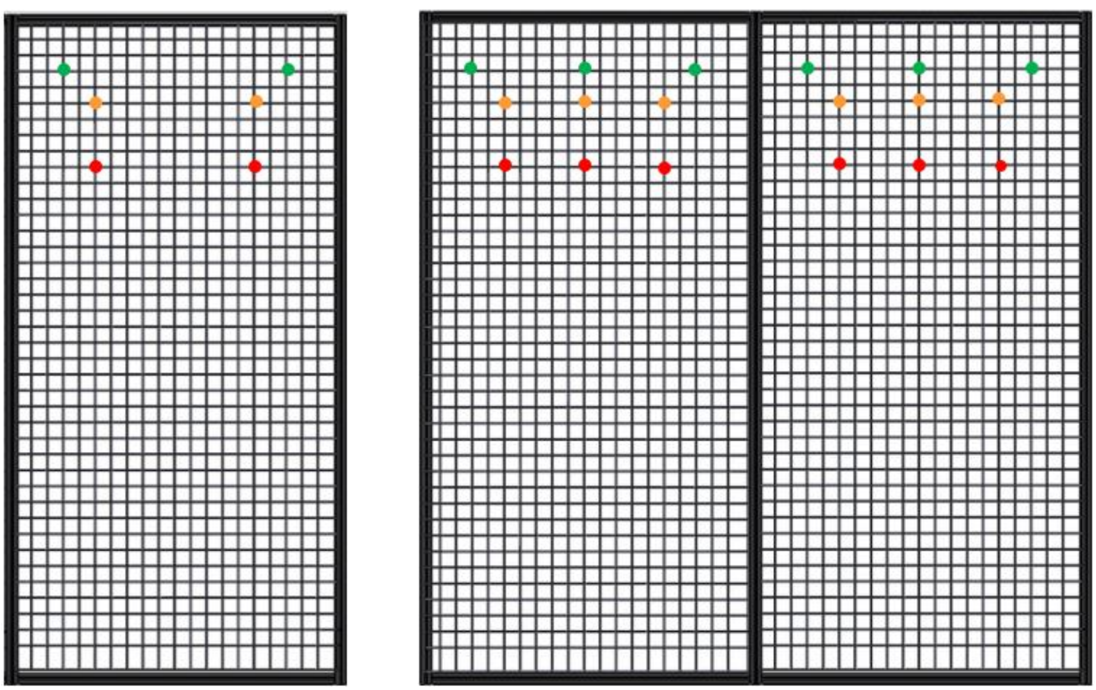

Image of test setup for group 2: back panel (left) and side panels (right) with test setup 1 in green, 2 in orange, and 3 in red.

C. Deflection Graphs

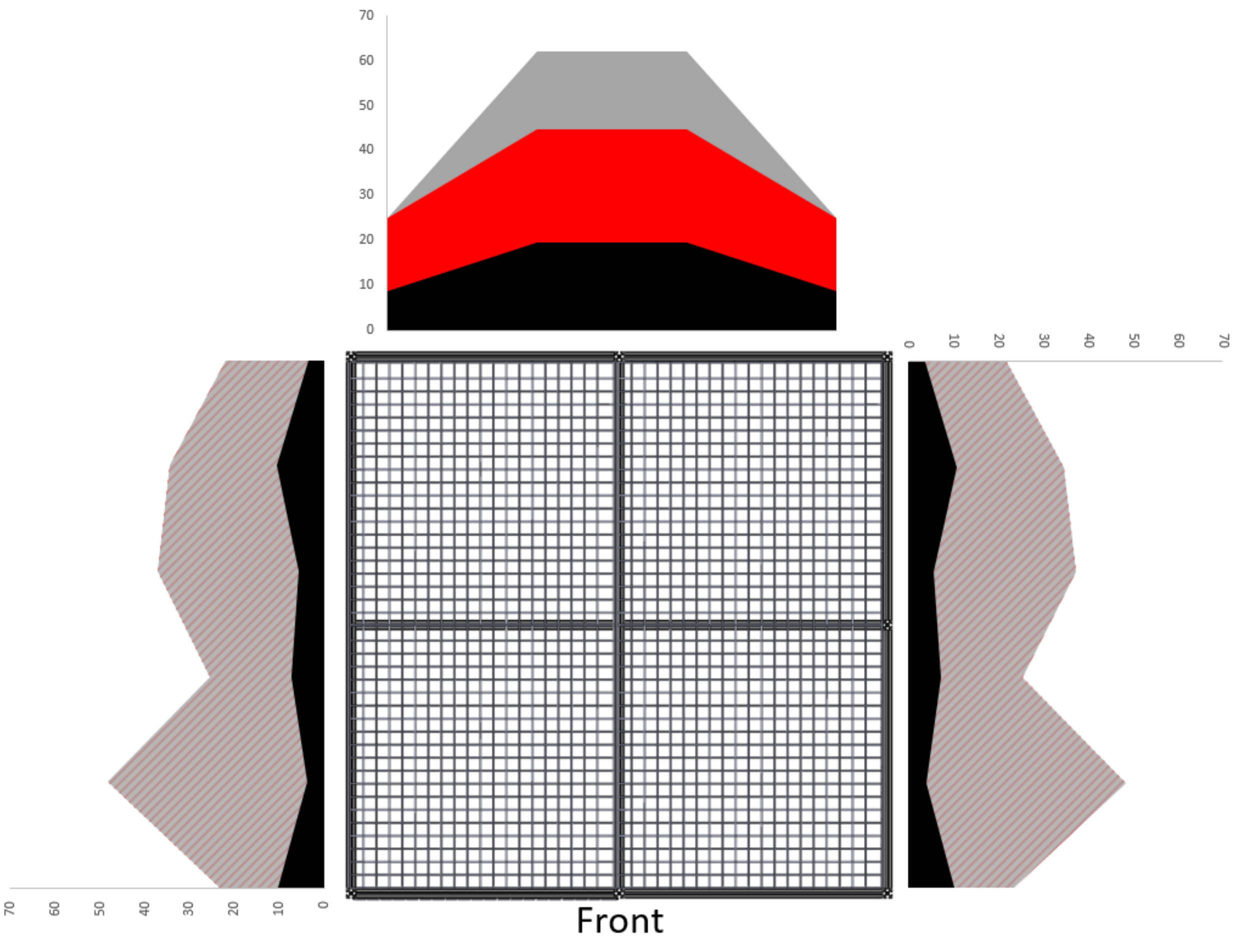

Image of deflection for Subject 1. Top view deflection visual for subject 1 from test setup 1 (black), test setup 2 (red stripes), and test setup 3 (gray) on the scale of thousandths of an inch.

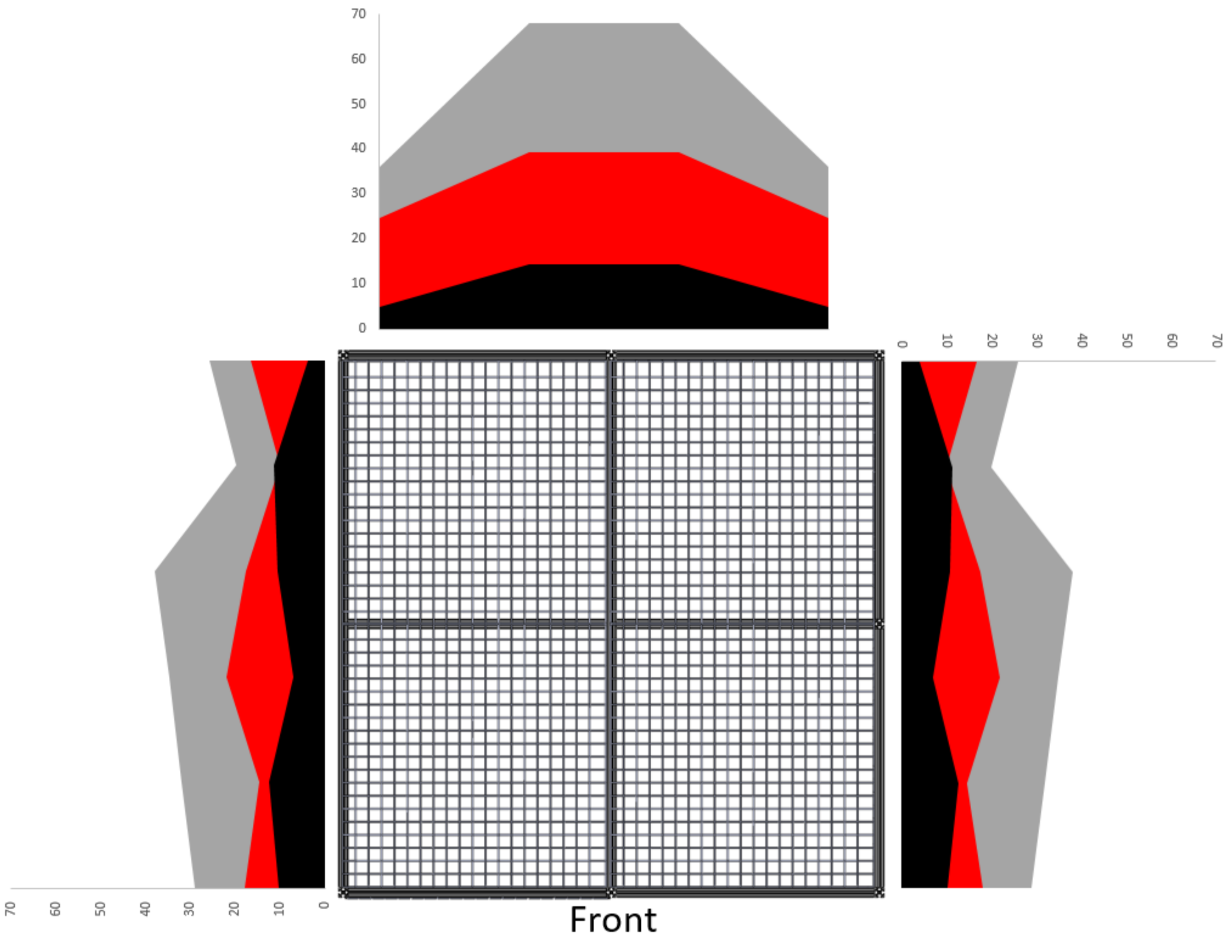

Image of deflection for Subject 2. Top view deflection visual for subject 2 from test setup 2 (black), test setup 2 (red), and test setup 3 (gray) on the scale of thousandths of an inch.

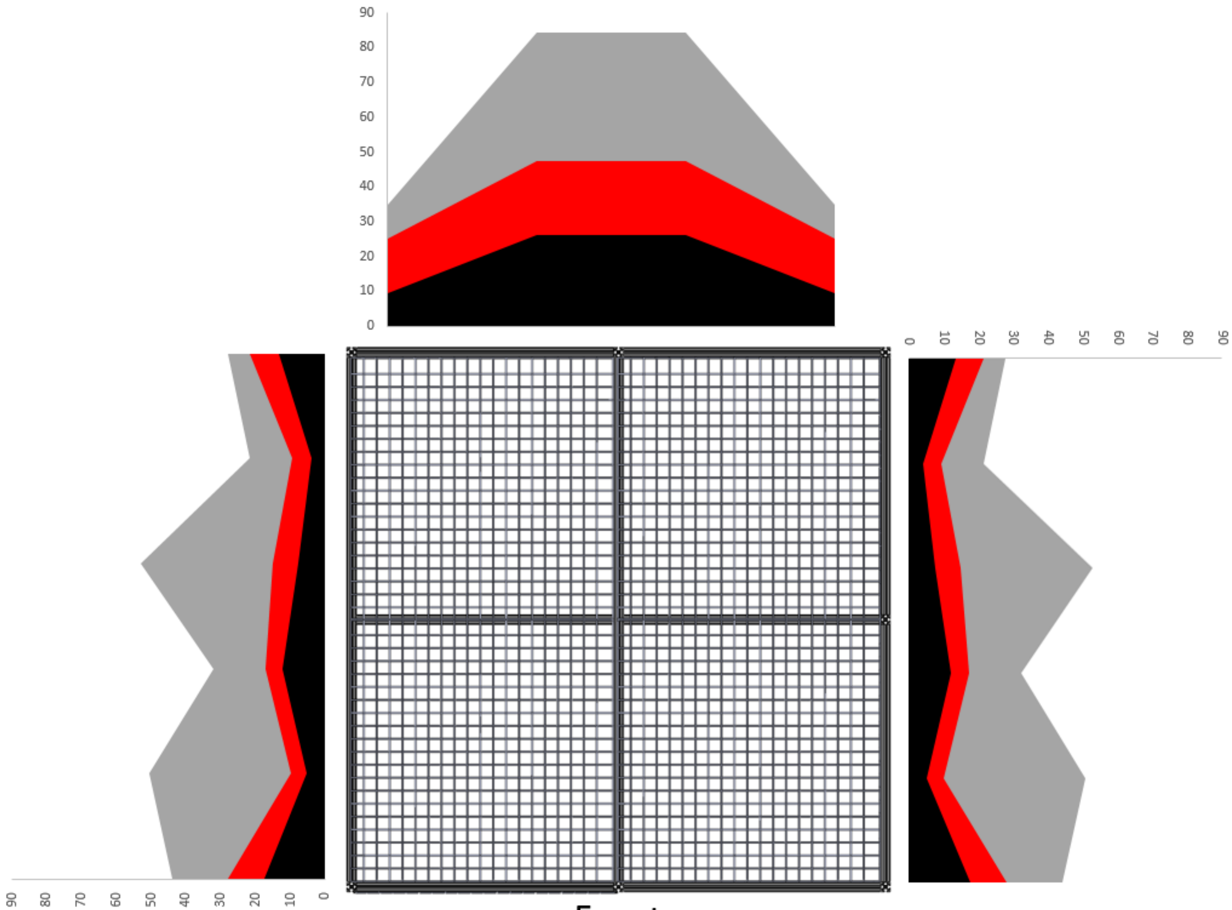

Image of deflection for Subject 3. Top view deflection visual for subject 3 from test setup 2 (black), test setup 2 (red), and test setup 3 (gray) on the scale of thousandths of an inch.

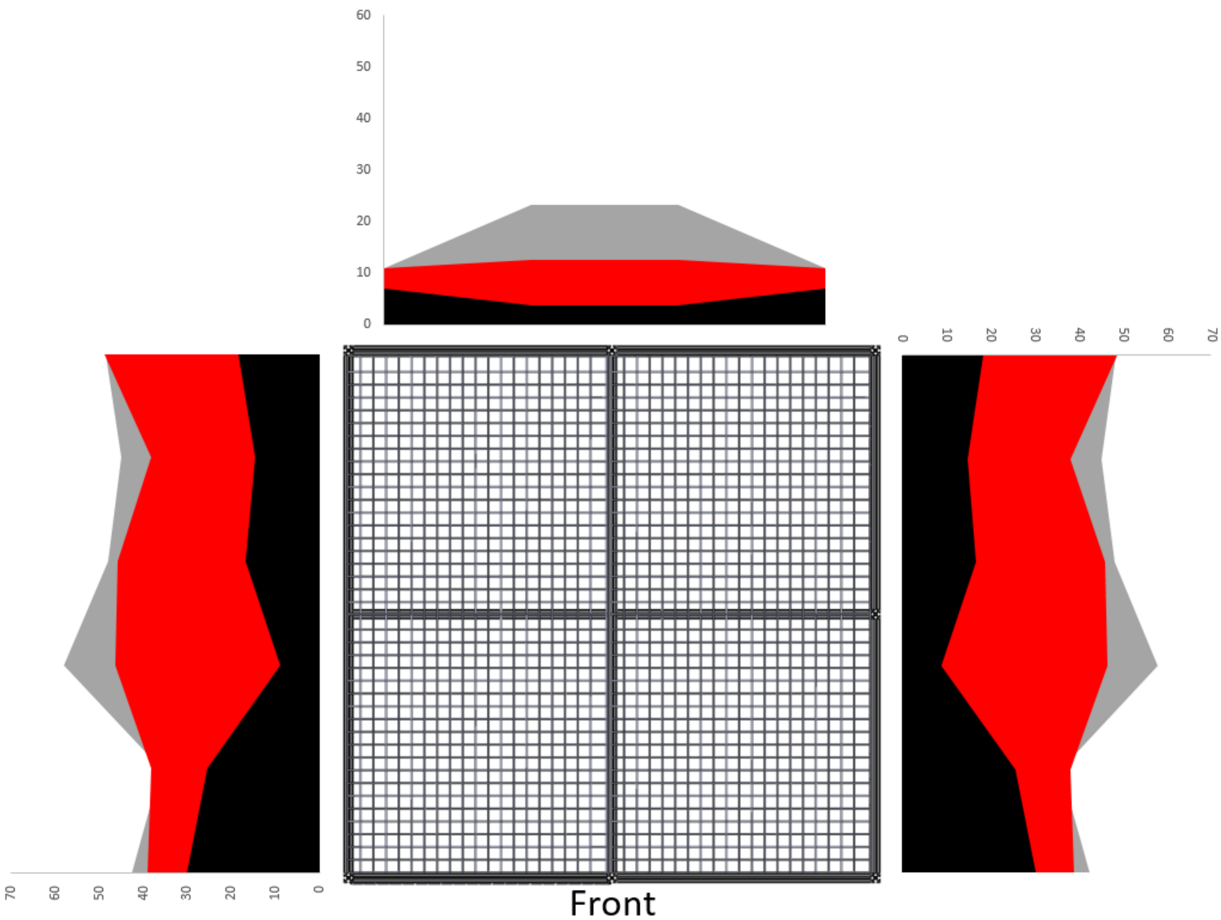

Image of deflection for Subject 4. Top view deflection visual for subject 4 from test setup 1 (black), test setup 2 (red), and test setup 3 (gray) on the scale of thousandths of an inch.

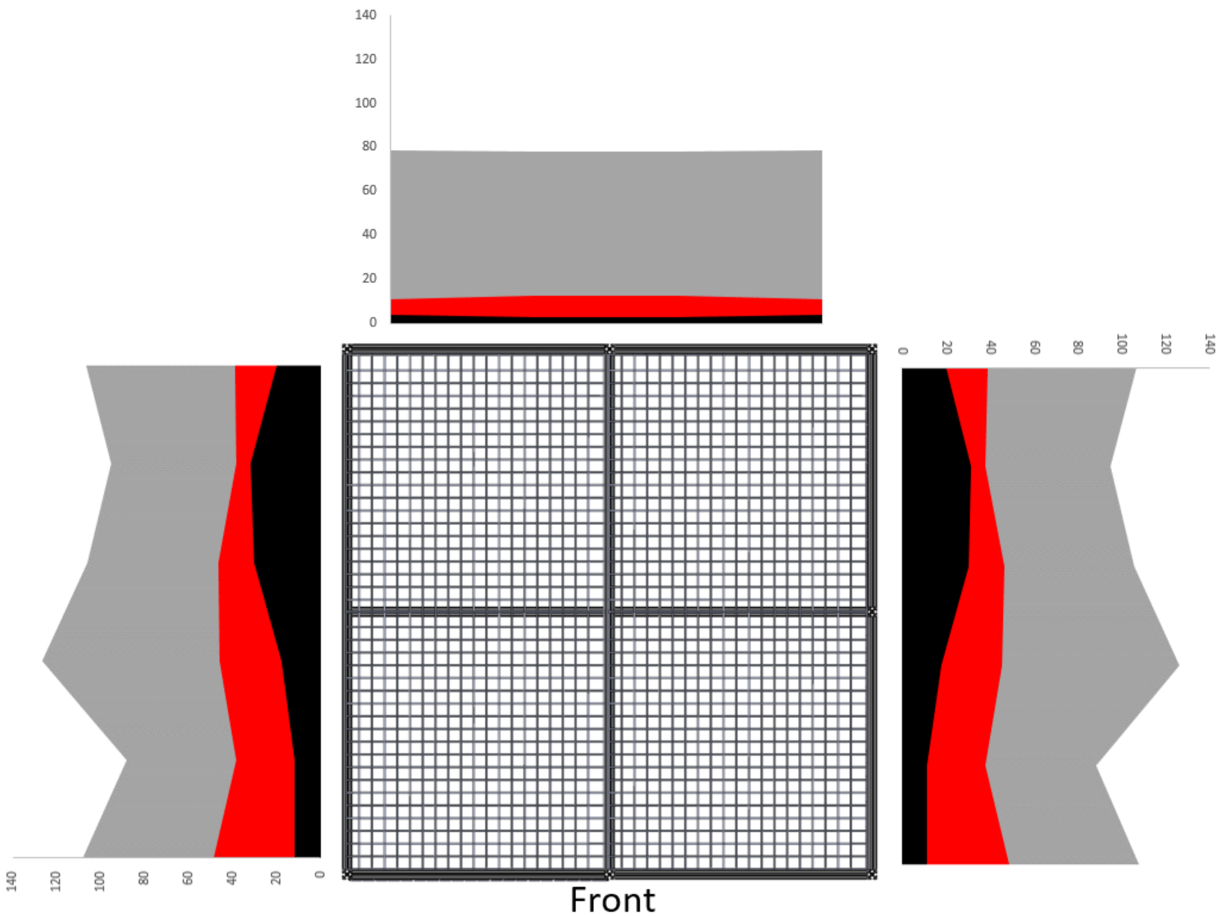

Image of deflection for Subject 5. Top view deflection visual for subject 5 from test setup 1 (black), test setup 2 (red), and test setup 3 (gray) on the scale of thousandths of an inch.