



THE UNIVERSITY
of
WISCONSIN
MADISON

DESIGN MATRIX: PREVENTING WEIGHTLIFTING INJURIES BY BARBELL MODIFICATIONS

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Biomedical Engineering 200/300: Biomedical Engineering Fundamentals & Design

Client: Mr. Robert Gold

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Design Matrix:

Design Categories (Weight/100)	Motion System		Barbell Weight Clips		Wrist Straps	
	5/5	30	4/5	24	4/5	24
Precision (30)	5/5	30	4/5	24	4/5	24
User Comfort (25)	5/5	25	5/5	25	3/5	15
Ease of Use (20)	2/5	8	5/5	20	4/5	16
Maintenance (10)	3/5	6	5/5	10	4/5	8
Ease of Fabrication (10)	2/5	4	4/5	8	3/5	6
Cost (5)	1/5	1	3/5	3	4/5	5
Total Points:	74		90		74	

Designs:



Figure 1. Motion System Design. A camera will be set up to track direct movement of the user, and this data will be recorded.

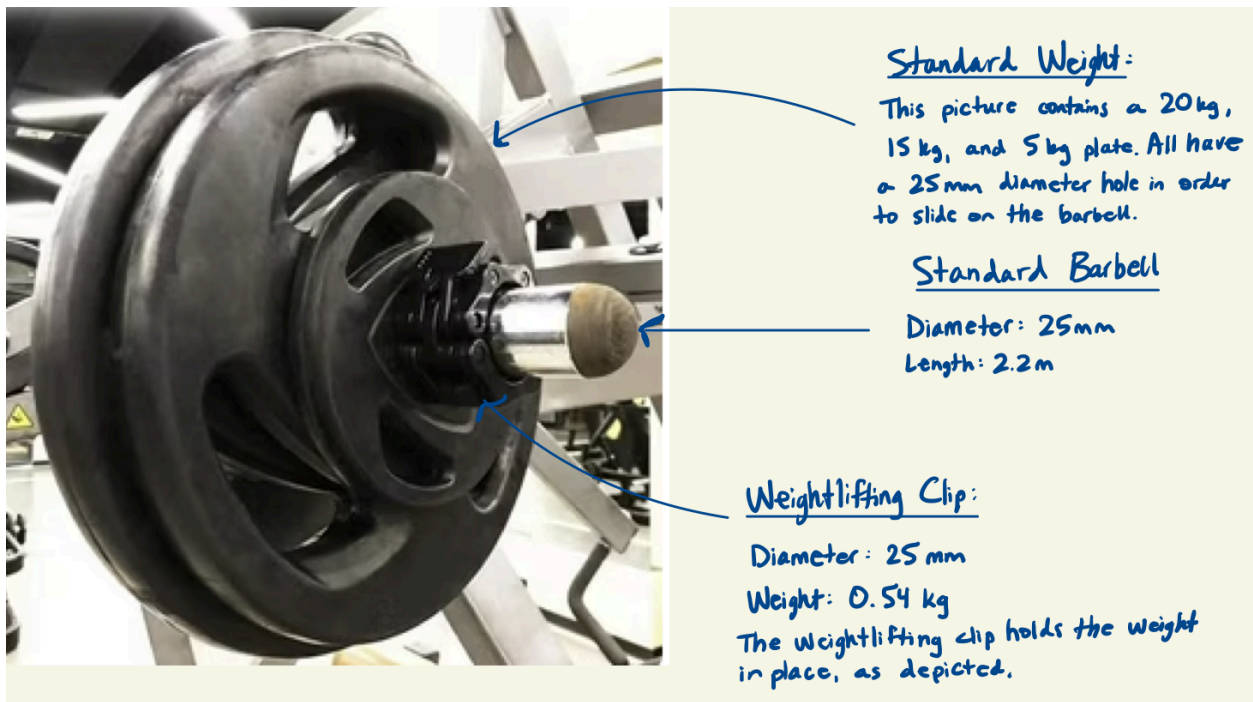
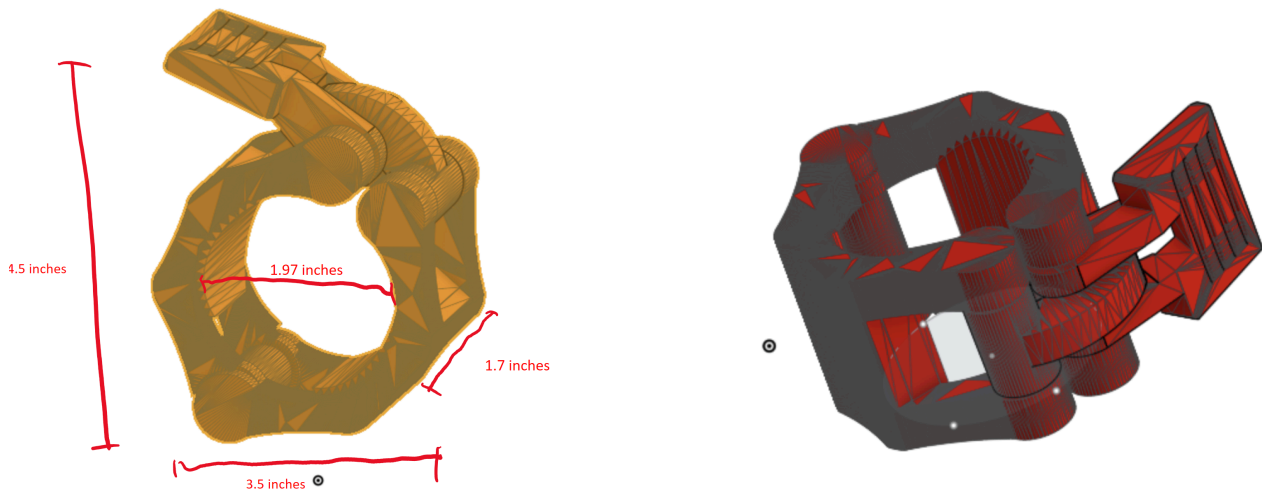


Figure 2. Barbell Weight Clips Design. An accelerometer will be housed within a modified but functional weight lifting clip that is used to clasp weight in place on the barbell.

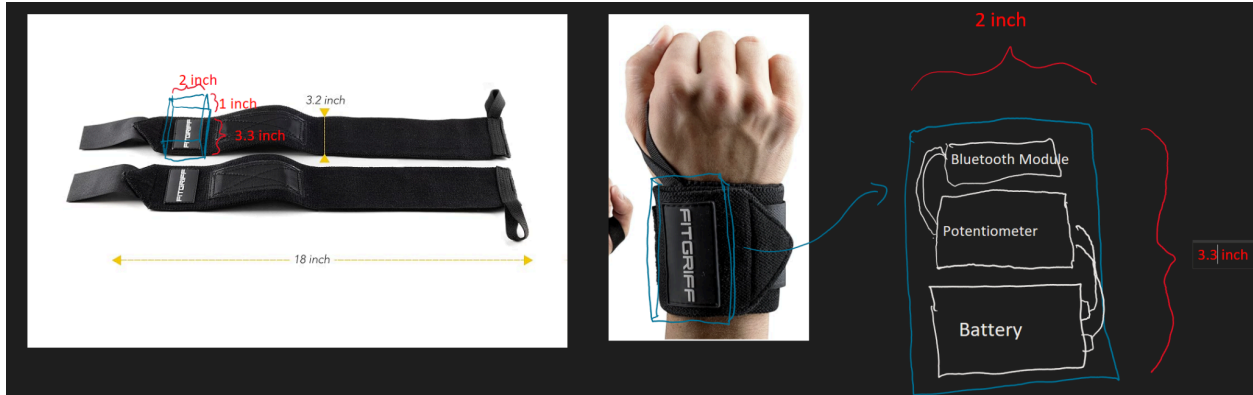


Figure 3. Wrist Straps Design. An accelerometer will be housed within a modified set of functional wrist straps that are used for wrist support when performing complex lifts such as the barbell bench press.

Design Category Descriptions and Evaluations:

Precision:

The precision category depicts how well the device tracks the movement of the barbell. Using existing literature and technical data, an exponential relationship will be expressed as the line of best fit. This line of best fit will represent the path of the barbell that will result in the best form and lowest injury rate when performing a complex lift such as the barbell bench press. Depending on the design model, this data will be collected in different ways. The precision of the injury prevention device will be quantified in inches, with an acceptable range of ± 0.5 inch from the determined line of best fit. Precision is the category that holds the most weight due to its crucial impact on the project. A narrow range is required to ensure the success of the product, as well as the wellbeing and safety of the user.

The Motion System was scored a 5/5 and assessed a 30 for its weighted score in the precision category on the design matrix. The Motion system as shown is a proven technology that can diagnose and assess data at the highest level. Quantitatively, this technology would succeed our requirements of precision. Both the barbell weight clips and wrist strap designs are comparable in the precision category of the design matrix. The Barbell weight clips design as well as the wrist strap design would both utilize Arduino microcontroller and accelerometer technology in order to assess and track barbell movement.

This technology will be successful and will be tested to be within the acceptable range of ± 0.5 inch, thus we scored both designs with a 5 and a weighted score of 24. Solely looking from a precision standpoint, the motion system would be the ideal design to move forward with.

User Comfort:

The user comfort category represents the degree to which the device is noticeable to the user while performing the lift. Comfort is a universal necessity when designing a product to be used on or by the human body. This classification is especially important because of the environment in which the device will be used. When undergoing a complex movement such as the barbell bench press, the user will be putting their body under great stress by pushing their physical limits. With the prevention of injury as our primary goal, the comfort of the user while undergoing these actions have been highlighted as a very important class within our design matrix.

The Motion system was scored a 5/5 and assessed a 25 for its weighted score in the user comfort category on the design matrix. The Motion system involves no contact with the user itself, thus giving it no way to discomfort the user in any way from a physical standpoint. The same goes for the barbell weight clips design, which was also scored a 5/5 and assessed a 25 for its weighted score. The weight clips design would be attached to the barbell itself, and would not have any contact with the user while performing a repetition. The wrist straps design was scored a 3 and assessed a 15 for its weighted score in this category. This difference stems from the direct contact between the user arm and the wrist strap. Wrist straps, when functional, can make a positive impact on the user's wrist stability when performing a lift such as the barbell bench press. However, it is material dependent in terms of user comfort, and with the addition of the sensor technology being added to the wrist strap, we have assessed the design lower when compared to the motion sensor and barbell weight clips design. Solely looking from a user comfort standpoint, either the barbell weight clamps or the motion system would be the ideal designs to continue forward with.

Ease of Use:

The ease of use category represents how easy it is for the user to both setup and use while lifting. Making our product easy to use is important because we want our product to be readily available for all users. We also want our product to be able to be used in regular commercial gyms, so our product can't take too much time to set up or use, otherwise it would hinder the users' lifting experience.

The Motion system scored a 2% for this category and had an 8 for its weighted score. This is because in order to use the motion system, you would need to set up a camera in the gym and make sure it won't be disturbed and it can see you at the right angle when you are benching. It would be a struggle to find enough space to put the camera at a suitable distance away from the bench in many commercial gyms. This is not the case for the barbell weight clip design which scored a 5/5 and a 20 weighted score in this category. The barbell weight clip design wouldn't take any more work to use than using a regular bench clip. All you would have to do is bring the clips into the gym and slide them on the barbell. The one problem with this is many people don't like benching with clips on without a spotter because it can be more dangerous, however, you can just slide the clips on without clamping them onto the bar which would allow the weight to slide off if needed. The wrist strap design scored a 4% and a weighted score of 16. This design would like to be easy to use in any gym as it doesn't take up any space, you would just need to bring it into your gym. The reason it isn't a 5/5 is that you need to learn how to put on wrist straps and how to bench with wrist straps. This is not hard to learn or do, but it is one extra thing the user would have to learn before using the design. Looking only from a ease of use perspective, the barbell weight clamps would be the ideal design to continue with.

Maintenance:

The maintenance category represents how hard and how much work the design would be to maintain and keep working. Making sure our product doesn't require too much maintenance is important because it would deter a lot of people from using it, and if there was a lot of maintenance it would be much harder for our client to use for a long time. While maintenance isn't the most important category it is still essential to make sure our product isn't hard to maintain and will not break easily.

The motion system scored a 3/5 in this category. The motion system has some things that would regularly need to be maintained. The camera lenses need to be cleaned if they are ever dirty and it needs to be stored inside where the camera would not be broken. You would also have to check to make sure the camera software is working properly with the camera, and it would be very hard to fix anything if it breaks. The barbell weight clamp scored a 5/5 in this category because there is almost nothing you would need to do to maintain it. The only thing that would need to be replaced is the batteries whenever they run out of charge. The wrist strap design scored a 3/5 because the materials for the strap on the wrist strap need to be replaced whenever there is any damage to them or if there is too much wear and tear on them. The wrist straps would get worn out much quicker because there is tension on the straps whenever they are in use so the material would eventually deteriorate, and would need to be replaced. Solely looking from a maintenance standpoint, the barbell weight clamps would be the ideal design to continue with.

Ease of Fabrication:

The ease of fabrication is a necessary constraint to consider. If there is an easy, realistic, and valid design that does not take any shortcuts or lack taking any variables into consideration which works just as well if not better than an equally valid design, which takes high amounts of time and requires an abundance of trial and error to fabricate, the design to be selected will most assuredly be the former.

The motion system scored a 3/5 in this category. The idea centered around using code referred to us by our client that centered around cameras which was believed to be applicable to this project. Upon further review the code was determined to be beyond the scope of our knowledge and possibly not even able to be applied to our system and situation in a realistic manner. The barbell clamp received a 4/5 in the ease of fabrication category. With limited technology needed to determine a coordinate system with which barbell movement can be tracked and a fabrication process as simple as trying to find a way to attach a little chip in the proper orientation to a barbell clip, this option is a very realistic possibility. The wrist straps received a 3/5 in the ease of fabrication category. This in large part was due to the larger variability in being able to receive accurate measurements due to the possibility of unequal placement of the wrist straps on the wrist. The team would also need to find a way to attach the motion chips needed to track

movement into the wrist straps without hindering mobility of the wrist or making them too bulky which is not as much of a concern regarding the barbell clamps. Solely looking from the ease of fabrication perspective the barbell clamps would be the ideal route to take.

Cost:

The cost category represents the expenses that will be incurred in the production of the design. Due to our allotted budget of \$300, it is imperative that we do not exceed this amount in order to create a fully functional and thoroughly tested device. While this category may not be a pressing concern for some ideas brought forward in the design matrix, it remains nonetheless important to keep in mind currently in the decision making process, but also throughout the duration of prototyping, fabrication, testing, and final design.

The motion system scored a $\frac{1}{5}$ in the cost category. This was in large part due to the costs that would be incurred buying two suitable cameras for the software as well as tripods on which they (the cameras) must stand. The estimated cost for the cameras alone would be somewhere in the range of \$600 to \$1000 which makes the motion system unrealistic for this aspect of the project. The barbell weight clips scored a $\frac{3}{5}$ in the cost category and the wrist straps scored a $\frac{4}{5}$. The decision behind the rankings for these two housing forms was comparative. While neither option is incredibly cheap (hence why no housing form received a 5/5 ranking), purchasing wrist straps is cheaper than the purchase of two barbell clamps. From a solely cost effective perspective this leaves wrist straps as the ideal route to take.