

Compound Barbell Weightlifting: Musculature via Sonification

John Guner

Georgia Institute of Technology

Atlanta, GA, USA

jguner3@gatech.edu

ABSTRACT

Body position within weightlifting is a complex structure that creates a high barrier of entry to functional exercise. The utilization of sound to identify key factors of body position within weightlifting may allow a stronger identification for people engaging in weightlifting. In order to dissect how sonification can enhance the experience we observe 3 healthy male experienced adults utilizing the application while performing their respective compound lift. I found that for certain compound lifts sonification can have a vital impact on positioning of certain joints, furthermore hand positioning can remain stable throughout each of the lifts allowing for consistency. During motion of each of the lifts, the perceived performance from the participants varied and I could not find a significant correlation between the application and their performance. Furthermore, the findings show that there was little to no risk of injury from the compound lifts after using the sonification tool. Knee contraction also reached a peak after the sonification tool was implemented increasing by an average of 1.67 degrees. Squat depth at peak range of motion increased by 1.33 inches as well.

Keywords

Weightlifting; compound lift; barbell; squat; bench press; deadlift; over head press; military press; shoulder press; sonification; sound assistance

INTRODUCTION

Weightlifting is on a popular uptrend from social media like Instagram, Facebook, and Twitter, getting far more people interested in their health and general fitness. Within the fitness sphere, weightlifting is a practice that enables muscles to adapt and get stronger by using weights to increase resistance against the muscles. Furthermore, this training regimen can be made up of exercises utilizing a lot of different muscles (compounds) and specific targeted muscle exercises (isolations), both can be further categorized in two separate categories: free weights (there is no machine assisting you with form), and machine (there is a machine assisting you with form). The key differences between free weights and machines are the assistance with form, free weights require you to have proper technique and stabilization of muscle groups whereas machines properly position your body to activate the intended muscles. For beginners form and technique can be difficult to learn properly and can result in permanent to fatal injuries, thus machines are easier to initially work with but not entirely safe. According to Mazur "The greatest risk of technique-related injuries occur during aggressive use of free weights in such

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exercises as the dead lift and bench press (Brown & Kimball 1983; Risser et al. 1990; Zemper 1990). Injuries using weight machines are also possible (Brady et al. 1982).", which explains that without proper technique compound lifts like the dead lift and bench press pose a higher risk of injury [3]. The drawback of using machines is that "hypotheses [are] based on the evidence that training with free weights activates more muscle mass, which should cause a greater increase in free testosterone, and over time causes a greater increase in muscle mass and strength" [4]. To optimally train and teach newer weightlifters proper form and range of motion, an audio-based interface that alerts the user when they are in proper start form and when the range of motion of the exercise is fully exhibited would help optimize training. Currently, the best method to learn proper range of motion on machines and compounds is to have a personal trainer or someone with enough experience to guide you, however it is not feasible for everyone to have a personal trainer due to scheduling issues, geographical complications, or financial problems, thus this interface could act as a substitute for beginners and those with less means to spend on health. To expand on this, poorer areas have less gyms and far less trainers than areas with higher incomes and being healthy is widely unconcerning as economic struggle and stress rapidly increases health issues. According to AAFP, "Poverty and low-income status are associated with various adverse health outcomes, including shorter life expectancy, higher infant mortality rates, and higher death rates for the 14 leading causes of death," [1]. This highlights the problems that lower income areas face, alongside how a cheaper alternative to personal trainers can curb the neglect of health exhibited in poorer areas. To circumvent these health issues Cattell notes, "for those involved in local activities, it is clear that participation has health promoting qualities," so engagement with the gym would lead to a better support system for poorer individual's health [5]. For this interface to be successful, body position and muscle strain must be logged to measure the effectiveness of an exercise. This can notify the user of the intensity of the exercise, if muscles are properly activating, and if their form is promoting the least possible risk of injury. Bodybuilders can also suffer from lower range of movement thus the interface must be adaptable and calibrated to each person, evidence of this is clear in Barlow's study concerning range of motion, "The results of this study have implications for body-builders, strength coaches, personal trainers, and health care providers in suggesting proper education and instruction on maintaining appropriate shoulder flexibility through performance and selection of proper resistance exercise to minimize the incidence of shoulder pathology." as bodybuilders tend to lose range of motion due to the increased muscle mass and posterior capsule tightness [2]. The primary objective of this project is to ensure weightlifters have a robust comprehension of their body movement and can pinpoint sound changes to their limbs allowing for ease of understanding limb position and activation. Furthermore, this objective is supplemented by programming better behaviors and protocols to weightlifting and reducing damaging muscle strain, thus reducing the risk of injury. This project is not limited to beginners nor

professionals but looks to expand the weightlifting experience for all training levels by acting as a focus allowing for lifters to hone in on their own performance.

In this investigation, the primary research questions I was interested in is to analyze if the lifter can interpret the various sounds presented to them, this is determined by if they can understand the correlation between sounds and their limb position if not, there are better ways in which the sonification could be less complex and intuitive for the user to understand. The primary research question is whether or not the sonification assists in performing the movements and if they recognize they are activating portions of their body.

METHODS

In this section, I describe my setting, participants, and detail the system setup and procedure to provide evidence and support replication.

Setting

The study took place at the Campus Recreation Center (CRC) gym at Georgia Institute of Technology's Atlanta campus. The CRC gym is one of the few full-scale gyms within the campus having hundreds to thousands of students, staff, alumni, and other gymgoers using equipment daily. The area used for the study was populated and relatively loud. The primary locations in which we conducted the study were at the bench press areas of the gym alongside the squat racks both of which had many occupants and a queue to use the equipment. At each location, there were a standard 45-pound barbell alongside the bench/power rack, an assortment of weights for the barbells and clips to ensure the weights stay on the barbell.

Participants

I recruited three male participants (ages 20-22), who gave their consent for the study. All three of which considered themselves familiar with the bench press and back squat. The drawbacks of this are the lack of diversity between the skill levels, sex, and ages so there is a significant portion of the population who this information has not been research on as of yet. Given these participants we decided that it would be best to have each participant perform at lower weights than they are used to alongside having them perform both back squat and bench press despite some of them being more adept at other compound lifts.



Figure 1. A participant prepares his hand position on the barbell before performing the back squat. This shows the environment and safety protocols with the power rack alongside all of the physical tools needed for this study.

Systems

To address the research questions, we determined that two versions of the study must be accomplished utilizing two separate motions, bench press and back squat. I discuss the physical equipment for

the study alongside the software and any intricacies adjusted within the study.

Equipment

The two stations had a barbell, a respective bench or safety rack depending on the exercise, a laptop to provide the simulation, arranged weights from 2.5 pounds to 45 pounds, and a safety clip to ensure the weights stay on.

Simulator and Procedure

To gauge how sonification would affect weightlifting form and body position I developed a simulator that sonifies movement based on JSON files and parameters. The parameters used were based on hand position, back position, and knee position. The simulator evaluates based off of x and y positions, muscle contraction, and range of motion. The simulator also has a function to allow the user to also experiment with real time data inputs in which affect the sounds played. The simulator uses varying frequency to indicate hand position, once hand position is proper the simulator will stop playing the frequency i.e., it goes to 0 Hz. The back contraction determines if the back has risk of injury and if it detects that there is a risk it will play sirens to indicate danger. The most innovative sonification lies in the knee contraction, a beeping noise's bpm increases as the participant contracts their knee more. Finally, the range of motion coincides with the contraction of the muscles and is also a frequency but in a different stage of activation meaning that first, hand position frequency plays and then after the movement is started the range of motion frequency will play.

In order to familiarize the participant with how the simulator works, I adapted the noise from the simulator to a video of me performing a proper back squat alongside a video of me properly changing hand positions, without assisting the participants on discerning the noise from the simulator. I then proceeded to ask the participants whether or not they could find a correlation between the video and the sounds being played in regards to the hand position portion of the video. After receiving a response, I note it and based on the response I give an accurate form of what the sonification is representing as described above. Continuing forward, the participant would then do their exercise without simulation interference, and we note the distance of the barbell from the ground, the knee contraction angle (back squat), and time it takes for the repetition to be completed. These are then noted and after t-



Figure 2. The UI for the simulator. The three buttons on the right coincide with preexisting datasets. The four sliders on the left are used for real time data inputs to simulate our participant's experience.

hey have completed the first set without the simulator, they then proceed to take a NASA Task Load Index assessment to assess the workload of the lift. This procedure is then repeated with the simulator to compare the data points.

RESULTS

In this section, I describe the analysis and discuss the findings for the guiding research questions.

RQ1: Are the sounds reasonable and intuitive for athletes to understand without prior knowledge?

I reviewed the three participants performance on understanding the sounds with guidance from the video. In all three cases the participants were able to understand that initial frequency was based on the hand position within the video. Furthermore, the danger alerts were also clearly understood when seeing a video in which a squatter is overcompensating and arching their back. The feedback from the participants on these two sound correlations were astonishingly intuitive and can be understood without prior knowledge. The case for muscle activation and range of motion was understood however the distinguishing between the two sounds was not nearly as successful as the prior two. Only one participant was able to properly understand the different sounds correlating with range of motion and muscle activation, regardless of these all three participants criticized this as it was a bit hard to distinguish with or without sound what the difference between range of motion and muscle activation are. They noted that the sounds were distinct however. All in all, this question is a bit more subjective and requires more data to make a confident statement thus we are left with mixed results.

RQ2: Does the sonification assist in performing the movements and recognizing muscle activation?

In order to accurately answer this research question, I made note of the objective data of the lifts alongside the subjective participants scores for the NASA TLX survey. I compared prior sonification results with the post sonification results for both of these data types and attempted to find a correlation between both prior and post sonification. We will first take a look at the objective data of the three participants on the back squat as well as their body dimensions. The dimensions of their body are important as it changes the range of motion detected based on their joint lengths. The knee angle is determined by the knee angle in relation to the calf and foot where 180 degrees is standing straight and 90 degrees is squatting at parallel.

Table 1. Displaying the dimensions of the participants alongside their weight in order to accurately assess the data retrieved from each exercise.

Participant	Height	Weight	Wingspan
1	6 feet 2 inches	210 pounds	6 feet 4 inches
2	5 feet 8 inches	150 pounds	5 feet 8 inches
3	5 feet 11 inches	200 pounds	6 feet

This information is pertinent and allows for an objective lens with respect to variations based on height since measurements can be heavily flawed. In order to account for this variation, I will take the differences between the two data sets and average the distance between the two data sets so that we account for any differences in height. Factors that will limit this dataset are limited participants, different barbell positions for back squat, alongside the participants individual ability to perform the motion. The actionability for hip

movement and the height disparity will also affect how the barbell affects each individual's range of motion.

Table 2. Displaying the objective data of the participants' back squat. This data is prior to the simulator assisting the participant in the motion.

Participant	Barbell from ground at rest	Barbell from ground at highest range of motion	Knee angle	Time
1	60 inches	34 inches	91 degrees	1.57 seconds
2	56 inches	29 inches	87 degrees	1.21 seconds
3	53 inches	27 inches	84 degrees	1.23 seconds

Table 3. Displaying the NASA TLX Scores for the three participants prior to sonification assistance, 0 indicates a very low rating for the physical demand whereas 21 indicates a very high physical demand so on and so forth. For performance 1 is indicative of a perfect performance.

Participant	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
1	5	4	1	2	3	1
2	1	2	4	1	2	1
3	2	1	1	1	2	1

Table 4. Displaying the objective data of the participants' back squat. This data is after using the simulator assisting the participant in the motion.

Participant	Barbell from ground at rest	Barbell from ground at highest range of motion	Knee angle	Time
1	60 inches	33 inches	89 degrees	1.62 seconds
2	56 inches	27 inches	85 degrees	1.34 seconds
3	53 inches	26 inches	83 degrees	1.45 seconds

Table 5. Displaying the NASA TLX Scores for the three participants after sonification assistance, 0 indicates a very low rating for the physical demand whereas 21 indicates a very high physical demand so on and so forth. For performance 1 is indicative of a perfect performance.

Participant	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
1	5	4	4	4	3	5
2	1	2	7	3	2	4
3	8	1	4	6	3	9

Discussion

In this section, I discuss the meaning behind the raw data displayed in the results section and conclusions that we can draw.

Criticisms

The NASA TLX shows that this sonification does not help focus all of our participants and can hinder their focus during the motion making it a bit more difficult to concentrate on the muscle activation. The third participant discussed that the sonification needed to be more user friendly and indicative of positioning while not being extremely distracting. Participant 2 also felt as if the bpm was a bit too fast making the lifter feel as if they are being rushed through the process rather than taking a slower and more deliberate approach allowing for less time activating muscles. These are both valid criticisms and will have to be updated in future iterations and be designed to create a better user experience.

Successes

Despite the aforementioned criticisms there were a few statistical successes in the objective data. One example is the depth of the squat from the lowest range of motion was deeper for all of the participants despite their critiques of the noise. The depth of inches for each participant was stronger by approximately 1.33 inches showing a solid increase in range of motion. All of them took a longer time to complete the rep, this is assumed to be correlated to trying to understand body position in regards to the sonification and the inclusion of more external stimulus. Furthermore, the knee angle was stronger than before; participant one commented on how the bpm encouraged a deeper squat and lead to a stronger motivation to get lower than before but nearly still parallel. The bpm was a prime motivator for him however the other two participants seemed to not be as enthusiastic about this change. All in all, none of the participants triggered the danger warning indicating that there was no risk in back injury during the squats however, all three mentioned that it would be a solid accompaniment to their regimen in case they do make an accidental mistake.

Conclusion

Weightlifters want to be exact when performing compound lifts to train optimally and reduce the risk of injury. Common tools to assist

them are partners and trainers however not everyone has the ability to have someone watch them every time they train. Weightlifters in this study were experienced enough to understand the back squat and bench press and evidently were curious regarding an application that can assist them to train optimally. This work looks to satisfy that urge to have scientific backed training protocols that are able to maximize the activation of muscles leading to enhanced hypertrophy, muscle gain, and strength progression alongside reducing the risk of injury. By comparing the data, it is evident that there is some merit to producing an accurate application that assists in the lifter's comprehension of body position and muscle activation. The results were a partial success, mainly being the objective data of the back squat depth and knee contraction improved over the course of the session with the sonification alongside no risk of injury being detected within the back of lifters. Though there were some drawbacks that need to be addressed these mainly being the sounds leading to cause distraction in the lifter, and some sounds creating a sense of urgency throwing off the user's tempo and mental understanding of their muscle activation. There is not enough data to make a strong assessment of the simulator on the general public as there were only three healthy college-aged male participants leaving room for a lot more participants to be observed. The strongest conclusion to be made from this research is that there is merit to pursue a stronger version of this application and that there is future potential in sonifying the body and muscles of weightlifters.

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