A Biomechanical Analysis of the *Weight Training Squat* Using Dartfish Motion Analysis Software

Introduction

Wesley Kephart was enrolled in the course Analysis of Movement, KIN 417, and in one of the co-requisite labs, KIN 417L, during the Fall 2010 semester term. His course long term project, A Biomechanical Analysis of the *Weight Training Squat*, was completed in the lab portion of the course. This project required the comprehension and utilization of various biomechanical principles, which he learned in the lecture portion of the Analysis of Movement class. The biomechanical principles, which are discussed in his project, are derived from Newton's Laws of Motion and assist us to understand the forces that produce and affect movement. The unique aspect of this project is that he was able to scientifically analyze the performance of the *Weight Training Squat*, by using the Dartfish Motion Analysis Software, which is the latest and most sophisticated computer video analysis software being used. This software is used by researchers, teachers, coaches, physical therapists, occupational therapists, and sports medicine specialists for detecting errors in a person's movements, calculating angles, times, distances, and velocities, and for providing feedback to the performer through the utilization of drawing tools and the production of a media book on a DVD. Stephen F. Austin State University is among an elite group of universities in the United States that has this sophisticated equipment.

Methods

•A videotape of the weight training squat was created requiring strict instructions.

•The videotape was imported, requiring strict instructions, into the Dartfish Motion Analysis computer **software.**

• The performance was critically analyzed by utilizing the drawing tools (*see pictures below*).

• Conclusions were drawn by applying biomechanical principles and personal knowledge of weight training kinesiology (*see comments beneath pictures*).

• Results were provided to the performer by utilizing the drawing tools to illustrate errors and producing a DVD media book.

The subject must be recorded holding a scaling rod as part of the videotaping procedure. This allows the software to accurately calculate life-size distances.

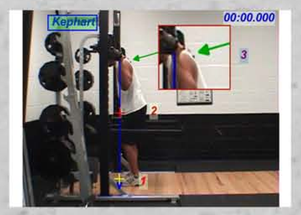
Abstract

During the Fall 2010 semester, Dr. Cole and her graduate assistant David Ware supervised students in a term project in which the students analyzed a movement of their choice using the latest computer version of the Dartfish Motion Analysis Software. In this project, a weight training squat was analyzed because it's considered to be the "king of all lifts," but it's frequently performed incorrectly.

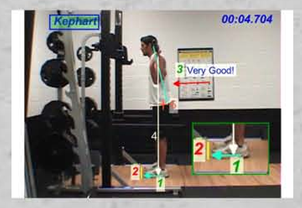
The biomechanical analysis involved videotaping two subjects, who performed the squat to the best of their ability. The subjects were instructed to wear clothing that contrasted with their skin tone and to have their knee and shoulder joints visible. To ensure accurate measurements, strict standards were followed during videotaping. A camera, containing a MiniDV cassette tape, was secured to a tripod and set up in a position where it was perpendicular to the plane of movement, in the middle of the range of movement while being as far away from the subject as possible, and level in all directions. The subject was then instructed to stand holding a scaling rod, which is an object of known length which allowed the software to calculate distances, and was recorded for ten seconds. Four trials were recorded per subject with a five second period of recording time before and after the completion of the squat. After the trials were completed, all data were imported into the Dartfish software.

After a careful review of the data, the average trials of the subjects were selected for an extensive and thorough movement analysis. Strengths and weaknesses of the movement were analyzed and illustrated by the many tools available within the software. The tools allowed the investigator to both quantify and qualify the correct and contraindicated movement patterns. Also, the investigator utilized his knowledge of physics and biomechanical principles to analyze and offer corrections to the various phases of the movement. For clarification of the recommendations, pictures were drawn with the Dartfish software and text was provided to further explain both the corrections and praises.

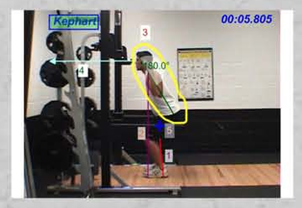
The investigator created a media book at the conclusion of the analysis to present the results and findings in a DVD format. The DVDs made it possible for the subjects to watch their movements with the analysis recommendations, so that, they could perform the weight training squat more safely, effectively, and efficiently.



Unracking- (1)The subject needs to ensure that efficient unracking requires his/her feet to be placed in a direct line under the bar.(2)Hips should also be placed under the bar for optimal force generation and minimal energy expenditure out of the rack. (3)When the subject's shoulder girdle is loose in this movement it could contribute to injury in the cervical or upper thoracic vertebra, in addition, the subject's scapula should be pulled back towards the spine (adduction). This adds to the subject's tightness of the posterior chain and minimizes injury. (4)The bar should be positioned lower on the subject's trapezius, which repositions the center of gravity and will make staying on the heels easier. These movements help secure the bar for the subject, so that it will not roll off the back and cause injury.

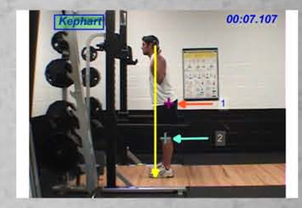


Set up- (1)Pointing toes forward is not optimal for efficient squatting. Toes should be pointed slightly outward (abduction). This helps the knees follow a linear path. If the subject were to go down to a 90 degree knee angle with the toes pointed forward, the subject would have to bow out to make it down to that point which increases the risk of injury.(2)For an efficient squat, the stance of the subject must not be too narrow. With a closer stance, there is a tendency for the knees of the subject to go past the toes and in order to make it down to the full squat, the knees often have to bow outward which increases the chances for injury. The knees should be turned out slightly (hip lateral rotation).(3)It is very good for the subject to keep the back straight to enhance performance and prevent injury. 4). The bar should be positioned to where the center of gravity falls within the base of support, which for most people will be the middle of the feet. (5)Due to the higher position of the bar, sometimes the hips do not fall within the line from the bar to the floor. A lower bar position would allow for optimal stability and force production.

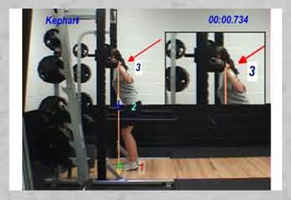


Descent phase- (1)The red line indicates where the shin of the subject was prior to the descent. For more efficient squatting motion, there should be minimal shin movement. Hip flexibility in order to "sit-back" into the squat position is very important for the subject. (2)The line of gravity that the bar follows should be over the feet of the subject. Placing the bar lower on the back will make this correction. Leaning forward with more weight can throw the subject off balance and make the squatting motion unstable and cause injury. (3)The subject's back should be in a straight line (180 degrees) for the optimal squat motion. Maintaining an isometric contraction in the lumbar region of the spine is pertinent for reducing the chances of injury (mainly disc herniation). (4)It is good for the subject to look straight forward to make sure the spine aligns and this is perfect for the full squat movement.(5) The eccentric (lengthening) contraction of the gluteals and quadriceps is crucial to controlling this movement. The control is important for maximum muscular and strength development.

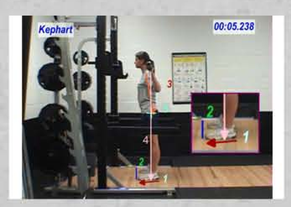
Angle of knee flexion- (1)The angle of knee flexion is typically dependent on femoral and tibial length for the subject. It does not matter that the angle is not 90 degrees. A full range of motion reduces the chances of muscular imbalances and promotes flexibility. (2)Having a knee past the toes can cause injury to the subject and is a very inefficient way to perform the squat. Working on hip and ankle flexibility would make "sitting back" in the squat easier to do for the subject. Also, placing the bar lower on the trapezius would make the squat more mechanically efficient.



The finished position- (1)The subject's hips are out of position with the line of gravity from the bar to the ground. This is a mechanically disadvantageous position and a difficult position to develop power from. Thus the subject's hips should be under the line of gravity under the bar to help prevent injury.(2)The subject's knees are out of position with the line of gravity from the bar to the floor. Yet again, this is mechanically disadvantageous for safety and power exertion reasons.



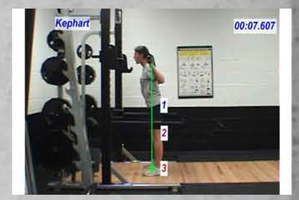
Unracking- (1)For more efficient unracking, the subject's feet should be placed in a direct line under the bar.(2)The subject's hips should also be placed under the bar for optimal force generation and minimal energy expenditure out of the rack.(3)The subject's shoulder girdle is in adduction, but it would be better if it was emphasized more. The scapula should be pulled back more towards the spine (adduction) to increase tightness. This makes the movement more powerful and also makes it more difficult to be loose and get injured. Also, positioning the bar lower on the trapezius, which repositions the center of gravity, will make staying on the heels easier.



Set up- (1)The subject's toes being pointed slightly out is optimal for the movement (abduction). By turning the subject's toes outward, the knees follow a more linear path.(2)The subject needs a broader stance to obtain a more efficient squat. With a closer stance, there is a tendency for the knees to go past the toes, which causes injury. A wider stance creates a larger base of support. The subject's knees should also turn out slightly (hip lateral rotation) and she should keep a straight back to prevent injury. (3)It is good for the subject to have the bar directly over the middle of the feet for the best support. However if the subject's knees are hyperextended (locked out), this is not an optimal stance to perform the squat.(4)It is very good for the subject to have the bar positioned over the center of the hips.(5)The bar is also in an optimal position over the shoulder girdle to the advantage of the subject.

The Descent phase- (1)The red line indicates where the subject's shins were prior to the descent. For efficient squatting motion, there should be minimal shin movement to prevent injury. It is beneficial for the subject to work on hip flexibility in order to "sit-back" into the squat position. (2)The line of gravity that the bar follows is over the front of the subject's feet. The bar should be over the center of the feet. Placing the bar lower on the trapezius will make this correction. Leaning forward with more weight will throw the subject off balance and make the squatting motion unstable.(3)It is good for the subject's back to be in a straight line (180 degrees). This is optimal for the squat motion. This indicates that the posterior side of the body is staying tight and the chances of lower back injuries are greatly minimized.(4)It is very good for the subject to look straight forward. Looking straight forward aligns the spine optimally and this is perfect for the full squat movement.

Angle of knee flexion- (1)Femoral and tibial length are the prime indicators for the possible knee flexion angle. In order for this to be a complete movement, the subject would have to go down to about 50.6 degrees for this to count in competition. However, it would be best to decrease the movement of the shin, so that the angle could be higher and the knees wouldn't go out past the toes. Therefore, the subject should still work on a full range of motion in order to minimize muscular imbalances and the promotion of flexibility.(2)It is not good for the subject's knees to be out past the toes. This can cause injury and it is an inefficient way to perform the squat. The bar should be placed lower on the subject's back and the hips should "sit-back". These corrections typically prevent the knees from going past the toes.



The finished position- (1)The subject's hips are out of position with the line of gravity from the bar to the ground. This is a mechanically disadvantageous position and a difficult position to develop power. Thus, the subject's hips should be under the line of the bar. A lower bar position would correct this error.(2)The subject's knees are out of position with the line of gravity from the bar to the floor. Yet again, this is mechanically disadvantageous for safety and power exertion reasons. This is another problem that the subject could fix with a lower bar placement.(3)Even though the subject's hips and knees are slightly behind where they should be, the feet are right in line. This is good because it has the subject's weight being placed over the middle of the feet, which is optimal for power exertion.

Summary

The Dartish Motion Analysis Software enabled the investigator to more efficiently view the performers' movements than with the known error of "eye balling it," and it allowed him to evaluate the performances using a sound scientific basis. It also allowed him to provide more detailed feedback for improvement to the subjects. The above images were used to publish a DVD media book, which was then given to the subjects as a permanent resource of the instructions and reasoning of performing the *weight training squat* in a manner that prevents injury.

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