A KINEMATIC COMPARISON BETWEEN GREATER-AND LESSER-SKILLED POWERLIFTERS DOING THE TRADITIONAL STYLE DEADLIFT

THESIS

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For the Degree of

MASTER OF SCIENCE

By

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Comparison kinematic models of the traditional style deadlift are presented. Data was obtained through film and analyzed via computer and computer graphics.

The comparison between the models revealed that the greater-skilled:

1. used less trunk flexion from the instant of initial trunk lean to the instant of maximum trunk lean,
2. used less knee extension (in same time interval as 1), and
3. demonstrated a smaller horizontal distance between the body center of mass (CM) and the CM of the bar at the instant the bar left the platform.

A trend was also observed in which the greater-skilled subjects demonstrated less thoracic lean than the lesser-skilled group at the time the bar reached knee level.
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CHAPTER I

INTRODUCTION

Competitive powerlifting is a relatively new sport. It was derived from the "odd lifts" in the U. S. and the "strength set" in Great Britain in the early 1960s (Todd, 1978). Its popularity has spread throughout the United States and the world. The three lifts which make up the sport are the squat, the bench press, and the deadlift.

Of the three lifts, the one that is believed to require the least amount of technique by powerlifters is the deadlift. Because of this, young lifters seem to rely mainly on mental excitation and little on technique. This type of approach has left lifters more susceptible to injuries in the back region.

The following is a summation of the official International Powerlifting Federation (IPF) rules for the deadlift (Todd, 1978):

The bar must be laid horizontally in front of the lifter's feet, gripped with an alternate grip with both hands, and uplifted with one continuous motion until the lifter is standing erect. At the completion of the lift, the knees must be locked and the shoulders thrust back. The referee's signal shall indicate the time when the bar is held motionless in the final position.
A list of causes for disqualification for the deadlift during competition are as follows (Todd, 1978):

1. stopping of the bar before it reaches the final position,
2. failure to stand erect,
3. failure to lock the knees,
4. supporting the bar on the thighs,
5. shifting of the feet during the performance of the lift,
6. raising of the heels or toes,
7. lowering the bar before the referee's signal to do so, and
8. allowing the bar to return to the platform without maintaining control with both hands.

The most used and accepted style for performing the deadlift is the so called "traditional style." In this style the lifter stands with a normal stance close to the stance used in the squat, then bends over and grasps the bar with an alternate grip outside of the knees. He then begins pulling the weight up until the torso is erect and the shoulders are locked back.

The following unique characteristics of the deadlift distinguish it from the other two lifts:

1. the deadlift is the only lift in which there is a pulling action,
2. the deadlift is the only lift which requires use of an alternate grip, and
3. the deadlift is the one that incorporates the most muscle groups.

Considering that powerlifting is a relatively new sport and that its
popularity is becoming more widespread, a scientific study focusing on the deadlift is overdue.

Purpose of the Study

The purpose of this study is to develop comparative kinematic models of the deadlift using greater- and lesser-skilled lifters; the greater-skilled model being valuable as a teaching tool.

Hypotheses

It was hypothesized that the comparison between the kinematic models would reveal that greater-skilled lifters:

1. use less trunk flexion from the instant of initial trunk lean to the instant of maximum (max) trunk lean,
2. use less knee extension from the instant of initial trunk lean to the instant of max trunk lean,
3. use less thoracic lean relative to trunk lean at the instant the bar is at knee level,
4. use a smaller trunk angle at the instant the bar is at knee level,
5. demonstrate a smaller horizontal distance between the body center of mass (CM) and the CM of the bar at the instant the bar leaves the platform, and
6. demonstrate a smaller horizontal distance between the body CM and the CM of the bar at the instant the bar reaches knee level.

These hypotheses were derived from the author's experience in powerlifting, review of the literature, and from the results of two
pilot studies presented in Chapter III.

**Delimitations of the Study**

The delimitations in the analysis of the deadlift include the following:

1. Only the traditional style deadlift was analyzed.
2. Ten subjects were used, five greater-skilled and five lesser-skilled.
3. Kinematic parameters were evaluated on the basis of two trials for each subject.

**Limitations of the Study**

The limitations in the analysis of the traditional style deadlift are included in the following:

1. Normal cinematographical analysis limitations were recognized.
2. The anatomical reference points necessary to make various computations were estimated for approximating the actual locations.
3. The subjects' movements were assumed to occur in a single plane perpendicular to the optical axis of the camera.
4. An external object was attached to each lifter and was assumed to stay stationary with respect to the segment to which it was attached.
5. The musculature of the lower and upper back was assumed to be representative of the lumbar and thoracic lean.

Definition of Terms

The following underlined terms are used with specific meaning in this thesis:

**Traditional style** refers to the most commonly used style of the deadlift in powerlifting. The lifter stands with a normal stance close to the stance used in the squat. He bends over, grasps the bar with an alternate grip outside of the knees and pulls the weight up until the torso is erect and the shoulders are locked back.

**Sumo style** refers to an alternate style of the deadlift in powerlifting. The lifter stands with a wide stance. He bends over, grasps the bar with an alternate grip inside of the knees and pulls the weight up until the torso is erect and the shoulders are locked back.

**Greater-skilled** lifter refers to a lifter that has deadlifted a weight which ranked him in the top 50 in the deadlift in powerlifting in his respective class in the United States.

**Lesser-skilled** lifter refers to a lifter that is not in the top 100 in the deadlift in powerlifting in his respective class in the United States and to a lifter who has competed in powerlifting contests for less than two years.

**Initial trunk lean** refers to the amount of lean the entire
trunk segment has at the instant the lift begins.

Trunk lean refers to the amount of lean the entire trunk segment has relative to horizontal.

Thoracic lean refers to the amount of lean in the thoracic musculature relative to horizontal.

Sticking point refers to the instant of the concentric mode of a lift in which bar velocity is at a relative minimum.

Bounce technique refers to a technique sometimes used in lifting in which the lifter increases velocity and somewhat relaxes in the final stages of the eccentric mode of the lift in order to cause a stretch reflex prior to the concentric mode.

Kinematic model refers to a group of kinematic parameters which help depict a particular technique.

Alternate grip refers to the hand grip used in the deadlift in which one hand is placed overhand on the bar with the opposite hand placed underhand.

Maximum attempt refers to a single lift in which the lifter attempts to lift the highest amount of weight possible.

Initial stage refers to the stage of the deadlift from the instant the lift begins to the instant the bar leaves the platform.

Shank refers to the lower leg segment of the subject and is used interchangeably with calf.

Eccentric mode refers to the negative stage of a weight lifting exercise in which the resistance is overcoming the active muscle.

Concentric mode refers to the positive stage of a weight lifting exercise in which the active muscle is overcoming the resistance.
The majority of scientifically-based literature dealing with weight lifting does not relate to powerlifting. There are numerous studies in which the Olympic lifts were used (Abramovsky, 1972; Enoka, 1979; Garhammer, 1978, 1979, 1980; Nelson & Burdett, 1978; Roman & Shakirzyanov, 1978, 1979), but very few which included powerlifting techniques. Unfortunately Olympic lifting studies and powerlifting studies have very little in common. Basically Olympic lifting involves two totally different lifts from those included in powerlifting.

Ariel (1974) was one of the first to conduct a study in which one of the powerlifts was used. The purpose of this study was to investigate the forces and moments of force activity about the knee joint during a full squat. Efficiency of lifting techniques was analyzed using negative (swaying forward) and positive (swaying backward) horizontal forces. The strongest and most experienced lifters demonstrated a horizontal force approaching zero while the lesser experienced demonstrated large negative horizontal forces.

Shear force in the knee joint was also investigated in Ariel's study. It was found that the highest shear force, besides the force exhibited in the beginning of the lift, was exhibited in the bottom of the squat. The lifters who did not utilize the bounce technique were the most experienced. These lifters also handled
the most weight and had drastically lower shear forces than the lifters that did utilize the bounce technique.

McLaughlin, Dillman, and Lardner (1977) conducted a study of the squat using world champion powerlifters of higher and lower skill levels. In this study they developed a kinematic model using bar velocity to compare the two levels of competitors. Their findings agreed with Ariel's study which illustrated that the lower-skilled lifters used more of a bounce technique while maintaining a much higher bar velocity in the descent phase of the squat. All lifters demonstrated a sticking point at the same relative phase of the ascent of the squat.

McLaughlin, Dillman, and Lardner (1978) also conducted a kinetic study using the same data. This study revealed that the higher-skilled subjects minimized trunk torque by 1) maintaining a more erect trunk, and 2) by increasing extensor dominant thigh torque, which in turn increased their performance. Little difference in results were observed in equations of dynamic motion as opposed to equations for the static condition. It was concluded that reasonable performance results can be obtained by using the simpler static condition method rather than the more complex dynamic motion method.

The bench press technique has also been analyzed by McLaughlin (1980). In his study top powerlifting bench pressers and novice bench pressers in the light and heavy classes were filmed. Comparisons were made on ascending bar path. For the initial stages of bar ascent, McLaughlin determined that for novice
lifters the bar path was vertical with a slight back horizontal direction change in the final stages. More experienced lifters used a vertical and back horizontal path to initiate ascent and became more vertical at the final stage. He concluded that by utilizing a horizontal back path in the initial stages of the ascent, the more experienced lifters were able to utilize additional muscle groups, thereby producing increased performance.

Nachemson and Elfström (1973) conducted a study which reflects on proper deadlift technique. Loads were measured on one lumbar vertebrae (L3 disc) on a 154 pound subject. The loads were measured via injection of a pressure sensitive device directly into the disc. Table 1 illustrates the findings and the importance of utilizing the bent knee style deadlift.

Table 1

<table>
<thead>
<tr>
<th>Activity</th>
<th>Force on Disc (LBS.)</th>
</tr>
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<tr>
<td>Lying down</td>
<td>112</td>
</tr>
<tr>
<td>Standing erect</td>
<td>225</td>
</tr>
<tr>
<td>Sitting upright (no support)</td>
<td>315</td>
</tr>
<tr>
<td>Lifting 44 lbs. with back straight and knees bent (as in a regular style Deadlift)</td>
<td>416</td>
</tr>
<tr>
<td>Lifting 44 lbs. with back bent and knees straight (as in a stiff legged Deadlift)</td>
<td>876</td>
</tr>
</tbody>
</table>

* Data from Nachemson and Elfström (1973)
Another important study relating to the deadlift is one conducted by Floyd and Silver (1955). Using electromyographic surface and needle electrodes the function of the erector spinae muscles was studied. Their important finding was that of a "flexion-relaxation" phenomenon. They determined that during 45 degree forward bending of the upper torso toward horizontal, there was complete relaxation for surface and deep erector spinae muscle. There was also no activity of those muscles in motion in the opposite direction until about 45 degrees to the horizontal, which meant the movement of the upper torso must be initiated by the hip extensors. It would also seem that the upper torso was solely supported by the ligaments of the lower back region during that portion of flexion and extension. The work of Floyd and Silver (1955) have proven valuable to deadlifters since their findings provide a technique with which the lower back ligaments can be protected from injury. Therefore, lifters should incorporate a technique minimizing extreme flexion of the upper torso (Floyd & Silver, 1955) and utilizing a bent knee style of the deadlift (Nachemson & Elfström, 1973).

In summary, few studies have been conducted which deal with powerlifting. No studies currently reported in the literature have directly involved the deadlift. In view of this, a scientific analysis of the deadlift is needed in the sport of powerlifting.
CHAPTER III

PROCEDURES

The purpose of this study was to develop comparative kinematic models of the deadlift using greater- and lesser-skilled lifters. It was assumed that greater-skilled lifters would act as the preferred model and thus serve as a valuable teaching tool. The methods and procedures that were used for collection and analysis of the data are presented in this chapter.

Pilot Studies

Two pilot studies were conducted in preparation for this study. In the first study, two subjects filmed during two maximum attempts using the sumo and traditional style of the deadlift were used to study differences in trunk angles. Trunk angles were obtained using film and the angle determination techniques listed later in this study (see page 25). It was determined for both subjects and both styles, maximum trunk lean occurred the instant the weight left the platform.

The second pilot study was conducted using five subjects of various body weights for the purpose of determining a method to locate the knee joint center when its perpendicular was obstructed by the plates of the lifting bar. It was determined that a stick twelve and one half centimeters long attached to the shank segment would provide the necessary information which would
allow the calculation of the knee joint center (see section on “attached stick”, page 14, and Figures 1 and 2).

Subjects

Ten male powerlifters were assigned to one of two groups, five greater- and five lesser-skilled. All previous performances of subjects from both groups were compared to the United States Powerlifting Federation (USPF) class deadlift rankings. Class rankings and years of experience were used as qualifiers for group placement. Both group qualifiers were applied to the subject population at the time data was collected. Greater-skilled subjects (n=5) were those that currently performed a deadlift which ranked them in the top 50 of the USPF class deadlift rankings. Average experience for the greater-skilled group was 10 years. Lesser-skilled subjects (n=5) were those whose best performance did not rank them in the top 100 of the USPF class deadlift rankings and who had less than two years of experience in powerlifting at the time the data was collected.

Instrumentation

The Power Bar and Plates

The bar and plates which were used in this study were competitive meet legal. They conformed to specifications established by the United States Powerlifting Federation (Todd, 1978).
Cinematographical Instrumentation

A high-speed 16mm motion picture camera (Model DBM-54, Teledyne Camera Systems, Arcadia, CA) was used to obtain film records of the subject's trials. The camera was set at 50 frames per second and positioned approximately 1.5 m above floor level with the optical axis directed towards the left side of each subject at a distance of 15.85 m from the subject. Proper leveling techniques were used so that the optical axis of the camera was directed along a horizontal line.

Two sets of cards used to identify the subjects and trials were number coded and included within the field of view of the camera and recorded on film. To provide a scaling factor, an object of known length was positioned horizontally in the anticipated sagittal plane of motion of the subjects and filmed before the actual trials.

Since the timing light and pulse generator were inoperable at the time of study, the free falling object method (Miller & Nelson, 1973) was used to calculate and insure proper film speed. The temporal scale was provided by releasing a ball at a known distance above the ground at various times during the filming. The film containing the ball drop frames was digitized to find two distances \( d_1 \) and \( d_2 \) from the initial drop height. The times \( t_1 \) and \( t_2 \) from the instant the drop occurred to the frames which were digitized were computed from the following equations:

\[
t_1 = \sqrt{\frac{2d_1}{g}}
\]
\[ t_2 = \sqrt{\frac{2d_2}{g}} \]  

where \( t \) = time and \( g \) is = 9.81 m/s\(^2\) (acceleration due to gravity).

By taking the number of frames between \( t_1 \) and \( t_2 \) and dividing it by the difference in time, frame rate is calculated by the following equation:

\[ \text{frame rate} = \frac{\# \text{ frames}}{t_2 - t_1} \]  

A plum bob was hung from the ceiling to provide a perfect vertical in the filming record. Figure 1 is a photo illustration of a subject performing an actual trial.

**Attached Stick**

As shown in Figure 1, a five inch stick was attached to the left shank of each lifter prior to the performance of each deadlift. The stick length was derived from the video analysis of a pilot study. It was attached with the aid of elastic and velcro materials. During film analysis this enabled one to calculate the location of the knee joint center when the plates were obstructing the perpendicular view of that joint center (see Figure 2). Figure 3 shows a diagram for the method of computing the knee joint center from stick endpoint and ankle joint center.
Figure 1. Photo illustration of subject performing trial. Note the plum bob to the left center of the subject and the attached stick on the left shank of the subject.
Figure 2. Example of attached stick & view obstruction of knee joint center.
Figure 3. Diagram for knee joint calculations using a 12.5 cm stick attached to the calf segment.

The variables and equations for obtaining the coordinates of the hidden knee joint center for a given frame $I$ are as follows (see Figure 3):

$$
\varphi = \tan^{-1} \left( \frac{Y(I,4) - Y(I,3)}{X(I,4) - X(I,3)} \right) \quad (4)
$$

where $\varphi = \text{angle between ankle-stick point line and horizontal}$, $4 = \text{stick point}$, $3 = \text{ankle point}$,

$$
\alpha = \tan^{-1} \left( \frac{Y(I,5) - Y(I,3)}{X(I,5) - X(I,3)} \right) \quad (5)
$$

where $\alpha = \text{angle between shank and horizontal}$, $5 = \text{knee point}$.

The knee point and ankle points were obtained when they were
visible during the filming of the trial.

\[ \beta = \alpha - \phi \]  

(6)

Where \( \beta \) = angle between shank and ankle-stick point line.

This angle was assumed to stay constant throughout the trial.

\[ L = \sqrt{(X(1,5) - X(1,3))^2 + (Y(1,5) - Y(1,3))^2} \]  

(7)

Where \( L \) = shank length, obtained when knee and ankle joints were visible during the trial.

Therefore, when the knee joint was obstructed by the weights the following equations were used:

\[ \alpha = \beta + \phi \]  

(8)

\[ x_k = L \cos \alpha \]  

(9)

Where \( x_k \) = horizontal coordinates of the knee joint center.

\[ y_k = L \sin \alpha \]  

(10)

Where \( y_k \) = the vertical coordinates of the knee joint center.

The assumption was made that the ankle joint center would
remain constant throughout the lift and that it was the axis of rotation for the shank.

Testing Procedures

All of the filming sessions were conducted at the location of MYO-TEK GYM (Denton, TX). Prior to each filming session, each subject was familiarized with assessment procedures and asked to read and sign a consent form for participation (see appendix B).

Two trials were filmed for each subject, one at 90% of the previous maximum attempt and one at 95% of the previous maximum attempt. Each subject was allowed a period of rest of at least five minutes, which is the upper limit of the minimum needed by the body to replenish the main energy source for powerlifting, adenosine triphosphate (ATP) (Fox, 1980).

Each subject was instructed to regard each trial as a maximum attempt. Prior to the performance of the first trial each subject performed his preferred warm-up. During the warm-up, the subjects wore the attached stick to insure that each was familiar with its feel. To facilitate the identification of the distal endpoint of the attached stick, a piece of black electrical tape was placed on the end of the stick (see Figure 2). During testing, a physician was on call in case of injury.

Data Analysis

Digitizing

For each successful attempt, the motion of the subject and motion of the bar were analyzed from the instant of initial
movement of the subject until the instant of erect standing with the bar. Analysis was accomplished with the aid of a Lafayette 16mm Analyzer (Lafayette Instrument Co., Lafayette, IN) in conjunction with a Numonics Electronic Graphics Digitizer (Model 1200, Numonics Corp., North Wales, PA), which was interfaced to a Tektronix 4052 Graphics Computer (Tektronix Inc., Beaverton, OR).

The x and y coordinates of body segment endpoints were digitized (see Table 2). Points that were digitized and not included in Table 2 were the center of the bar and the stick point. The final three segments in Table 2 were derived from the analysis of video tape of a previous pilot study in which lifters illustrated flexion at points in their musculatures. The segment of most interest being that of the thoracic region, T10-L1 flexion point, in which the upper back has a rounding effect. These flexion points correspond with the White and Panjabi study (1978) in which the most flexion and extension were in those areas (see Figure 4). The prominences used for analysis were also used as landmarks in a study by Drerup and Hierholzer (1985) to determine surface curvatures in the back.

All the raw data were smoothed using a digital filter technique at a cut-off frequency of 4 Hz (Winter, Sidwall, & Hobson, 1974).
Figure 4. Functional motion of the spine. Figure from Frankel and Nordin (1980), based on data of White and Panjabi (1978).
Table 2

**Body Segment Endpoints**

<table>
<thead>
<tr>
<th>Segment</th>
<th>Proximal Endpoint</th>
<th>Distal Endpoint</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Vertex *</td>
<td>Chin-neck intersect*</td>
</tr>
<tr>
<td>Trunk</td>
<td>Suprasternal notch*</td>
<td>hip joint</td>
</tr>
<tr>
<td>Upper arm</td>
<td>Shoulder joint</td>
<td>Elbow joint</td>
</tr>
<tr>
<td>Forearm</td>
<td>Elbow joint</td>
<td>Wrist joint</td>
</tr>
<tr>
<td>Hand</td>
<td>Wrist joint</td>
<td>Knuckle III*</td>
</tr>
<tr>
<td>Thigh</td>
<td>Hip joint</td>
<td>Knee joint</td>
</tr>
<tr>
<td>Shank</td>
<td>Knee joint</td>
<td>Ankle joint</td>
</tr>
<tr>
<td>Foot</td>
<td>Heel*</td>
<td>Tip of long toe*</td>
</tr>
<tr>
<td>Thoracic region</td>
<td>C7 prominence</td>
<td>T10-L1 (place on musculature where most flexion is seen between thoracic and lumbar region)</td>
</tr>
<tr>
<td>Lumbar region</td>
<td>T10-L1 (place on musculature where most flexion is seen between thoracic and lumbar region)</td>
<td>L5-S1 (place on musculature where most flexion is seen between lumbar region &amp; sacrum)</td>
</tr>
<tr>
<td>Sacrum</td>
<td>L5-S1 (place on musculature where most flexion is seen between lumbar region &amp; sacrum)</td>
<td>Coccyx prominence</td>
</tr>
</tbody>
</table>

* See Clauser et al. (1969) for definitions.

† Used for calculation of angular displacements of lumbar and thoracic regions.
### Table 3

**Masses of Body Segments Relative to Total Body Mass**

<table>
<thead>
<tr>
<th>SEGMENT</th>
<th>RELATIVE MASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>0.073</td>
</tr>
<tr>
<td>Trunk</td>
<td>0.507</td>
</tr>
<tr>
<td>Upper arm</td>
<td>0.026</td>
</tr>
<tr>
<td>Forearm</td>
<td>0.016</td>
</tr>
<tr>
<td>Hand</td>
<td>0.007</td>
</tr>
<tr>
<td>Thigh</td>
<td>0.103</td>
</tr>
<tr>
<td>Calf</td>
<td>0.043</td>
</tr>
<tr>
<td>Foot</td>
<td>0.015</td>
</tr>
</tbody>
</table>

* Adapted from data presented in Clauser et al. (1969)

### Table 4

**Location of Centers of Mass of Body Segments**

<table>
<thead>
<tr>
<th>Segment</th>
<th>Center-of-Mass location Expressed as percentage of total distance between Reference Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>46.4% to vertex; 53.6% to chin–neck intersect</td>
</tr>
<tr>
<td>Trunk</td>
<td>43.83% to supra sternal notch; 56.17 to hip axis*</td>
</tr>
<tr>
<td>Upper arm</td>
<td>47.13% to shoulder axis; 52.87 to elbow axis#</td>
</tr>
<tr>
<td>Forearm</td>
<td>39.0% to elbow axis; 61% to wrist axis</td>
</tr>
<tr>
<td>Hand</td>
<td>82.0% to wrist; 18.0% to knuckle III</td>
</tr>
<tr>
<td>Thigh</td>
<td>39.40% to hip axis; 60.6% to ankle axis*</td>
</tr>
<tr>
<td>Calf</td>
<td>40.95% to knee axis; 59.05% to ankle axis*</td>
</tr>
<tr>
<td>Foot</td>
<td>44.9% to heel; 55.1% to tip of longest toe</td>
</tr>
</tbody>
</table>

* Adapted from data presented in Clauser et al. (1975).
* Corrections by Hinrichs (1982).
Center of Mass

The digitized data, excluding the last three segments on Table 2, were used in conjunction with a computer program which computed, at each of the instants analyzed, the x and y coordinates of the center of mass of the body. The relative mass of each human body segments used in the study were derived from those computed by Clauser, McConville and Young (1969), (see table 3). The location of CMs of body segments are listed in Table 4. The method used for calculating the subject’s CM in each particular frame is outlined in the following steps (Hay, 1985).

1. The length of the various segments was determined by using the x and y coordinates of each segment’s endpoints.
2. The orientation of the x and y coordinates of the CM of each segment was obtained using data from Table 4.
3. The moments of mass for each segment about the x and y axes (OX and OY, respectively) were calculated by multiplying the x and y coordinates, respectively, by their mass proportions shown in Table 3.
4. The sum of the moments, ΣOX and ΣOY, were then calculated.

Since filming was done perpendicular to the sagittal plane of the subject, left segments of the body were assumed to be representative of the right segments of the body; therefore, those particular segments are multiplied by 2.

\[
\Sigma OX = OX(foot) \times 2 + OX(calf) \times 2 + OX(thigh) \times 2
\]
\[ + \text{OX(trunk)} + \text{OX(head)} + \text{OX(upper arm)} \times 2 + \]
\[ \text{OX(forearm)} \times 2 + \text{OX(hand)} \times 2 \]
\[ \Sigma \text{OX} = \text{OY(foot)} \times 2 + \text{OY(calf)} \times 2 + \text{OY(thigh)} \times 2 + \text{OX(trunk)} + \text{OY(head)} + \text{OX(upper arm)} \times 2 + \]
\[ \text{OX(forearm)} \times 2 + \text{OY(hand)} \times 2 \] (11)

\[ \Sigma \text{OY} = \text{OY(foot)} \times 2 + \text{OY(calf)} \times 2 + \text{OY(thigh)} \times 2 \]
\[ + \text{OX(trunk)} + \text{OY(head)} + \text{OX(upper arm)} \times 2 + \]
\[ \text{OX(forearm)} \times 2 + \text{OY(hand)} \times 2 \] (12)

\(\Sigma \text{OX}\) gives the horizontal coordinate of the CM of the subject and
\(\Sigma \text{OY}\) gives the vertical coordinate of the CM of the subject. The horizontal distance between the CM of the body and the CM of the bar was then analyzed.

**Angles**

Segment angles were computed relative to the positive \(x\) (horizontal) axis. These angles were shank angle \((\beta_1)\), thigh angle \((\beta_2)\), trunk angle \((\beta_3)\), and thoracic angle \((\beta_4)\).

The equation used for these computations was as follows:

\[ \beta = \tan^{-1}((Y(P) - Y(D)) / X(P) - X(D)) \] (13)

Where \(\beta = \) segment angle, \(P = \) proximal joint of the segment, and \(D = \) distal joint of the segment.

Because \(\tan^{-1}\) is defined only for quadrants I and IV, if \(\beta\) was located in the second or third quadrant 180 degrees was added to the angle.

Knee joint angle \((\phi)\) was also computed and the equation used to derive this is as follows:
\[ \phi = (180 - \beta_1) + \beta_2 \]  

(14)

Figure 5 contains stick figures illustrating the angles that were analyzed.
Statistics

Curves of the following kinematic parameters as functions of time were used for analysis:

1. Trunk angle ($\beta_1$).
2. Knee angle ($\phi$).
3. Thoracic angle ($\beta_4$).
4. Horizontal distance between CM of the bar and CM of the lifter.

Six t-tests ($\alpha = .05$) were used to test for significant differences between groups for specific instances on the curves. These instances were:

1. trunk flexion angular displacement from instant of initial trunk lean to the instant of max trunk lean,
2. knee extension angular displacement from the instant of initial trunk lean the instant of max trunk lean,
3. difference of angles between thoracic lean and trunk lean at the instant the bar is at knee level,
4. trunk angle at the instant the bar is at knee level,
5. horizontal distance between CM of the bar and CM of the subject at the instant the bar leaves the floor, and
6. horizontal distance between CM of the bar and CM of the subject at the instant the bar is at knee level.
CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to develop a comparative kinematic model of the deadlift using greater- and lesser-skilled lifters. The kinematic model produced was that for the initial stage of the deadlift. The parameters which the model contains are that of trunk angle, knee angle, thoracic angle, and horizontal difference between CM of the bar and CM of the body. This chapter includes the results and a discussion of results of this study.

Results

Figures 6A and 6B illustrate the typical curves for the trunk angle of greater-skilled and lesser-skilled groups. All typical angle curves are of a particular lesser-skilled subject and a particular greater-skilled subject which illustrate the means of each group. Point A marked on each curve is the instant of initial trunk lean with point B being the instant when the weight left the platform. The results showed that the greater-skilled group tended to flex the trunk less between the instant of initial trunk lean and the instant of max trunk lean and bar off.
**Figure 6A.** Typical trunk angle, greater-skilled group.  
(A = initial trunk lean, B = max trunk lean & bar off, C = bar at knee level)

**Figure 6B.** Typical trunk angle, lesser-skilled group.  
(A, B, C same as Figure 6A)
The mean flexion angles with standard deviation (SD) in degrees were $5.1 \pm 1.24$ and $13.5 \pm 6.14$ for the greater-skilled and lesser-skilled groups, respectively. The difference was statistically significant ($p < .05$).

Figures 7A and 7B illustrate the typical curves for the knee angle for the greater-skilled and the lesser-skilled groups. Points A and B marked on each curve correspond to the same points marked in figures 6A and 6B. The change in knee angle from point A to B is termed "knee extension angle". The mean knee extension angles ($\pm$ SD in degrees) were $10.9 \pm 4.6$ and $23.2 \pm 7.42$ for the greater and lesser-skilled groups, respectively. The greater-skilled group showed less knee extension. The difference was statistically significant ($p < .05$).

Figures 8A and 8B illustrate curves for the thoracic angle and trunk angle for the two groups. Point C on each curve marks the instant when the bar was at knee level. The difference between the trunk and thoracic angles of the group means at this instant was tested. The mean angle differences ($\pm$ SD in degrees) were $6.7 \pm 1.96$ and $13.0 \pm 6.17$ for the greater and lesser-skilled groups, respectively. This difference was not statistically significant ($p < .05$).

The trunk angle (trunk lean) was also tested at point C, the instant the bar was at knee level for the two groups (see figures 6A and B). The mean angles ($\pm$ SD in degrees) were $143.4 \pm 9.21$ and $143.2 \pm 6.92$ for the greater and lesser-skilled groups, respectively. The difference was not statistically significant ($p < .05$).
Figure 7A. Typical knee angle, greater-skilled group.
(A = initial trunk lean, B = max trunk lean)

Figure 7B. Typical knee angle, lesser skilled group.
(A & B same as Figure 7A)
**Figure 8A.** Typical thoracic with trunk angle, greater skilled. (C = bar at knee level)

**Figure 8B.** Typical thoracic with trunk angle, lesser-skilled group. (C = bar at knee level)
Figures 9A and 9B each illustrate two curves, one for the horizontal displacement of the CM of the bar and the other for the horizontal displacement of the CM of the lifter. Points B and C are the same instances of time illustrated in the previous figures. The horizontal distance between the two groups centers of mass at point B was examined. The mean distances (± SD in cm) were 24.65 ± 1.88 and 28.42 ± 2.44 for the greater and lesser-skilled groups, respectively. The difference was statistically significant (p<.05).

The horizontal distance between the two centers of mass of the two groups was also tested at point C. The mean distances (± SD in cm) were 19.5 ± 2.18 and 19.4 ± 2.48 for the greater and lesser-skilled groups, respectively. The difference was not statistically significant (p<.05).

Although no hypothesis had been formulated concerning movement times, a post hoc t-test was conducted for the mean time it took the two groups to go from the point the bar left the platform to the point the bar reached knee level. The means (± SD in seconds) were 0.63 ± 0.13 and 0.95 ± 0.26 for the greater and lesser-skilled groups, respectively. This difference in time was statistically significant (p<.05).

The statistics for all the tests are summarized in Appendix A.
Figure 9A. Typical curves of horizontal displacements of the center of mass of the bar and lifter, greater-skilled group. (A = initial trunk lean, B = bar off, C = bar at knee level)

Figure 9B. Typical curves of horizontal displacements of the center of mass of the bar and lifter, lesser-skilled group. (A, B and C same as Figure 9A)
Discussion

The kinematic model produced by this study provides some important findings for the initial stages of the deadlift. The initial stage, from the instant of initial trunk lean to the instant of max trunk lean, the greater-skilled lifters demonstrated less trunk flexion than the lesser-skilled lifters. The greater-skilled lifters also demonstrated less knee extension between these two instances of time than the lesser-skilled lifters.

These two findings seem to illustrate that the greater-skilled lifters maintained a tighter upper torso to initiate the initial movement of the bar. This was probably because of stronger musculature in the trunk region, which enabled them to be more upright for the execution of the lift. Also, less knee extension enabled the greater-skilled lifters to have better hip leverage position for the completion of the lift. This was probably also due to the stronger musculature in the trunk region of the greater-skilled lifters.

Even though the difference between thoracic angle and trunk angle at the instant the bar was at knee level was not significantly different, there was a trend for the greater-skilled lifters to have less of a difference between these two angles than the lesser-skilled. This also would seem to illustrate that the greater-skilled lifters are at a better leverage position at the middle stage to complete the lift. The reason for this is probably because of the stronger musculature of the thoracic region in the greater-skilled lifters.
The greater-skilled lifters also showed smaller horizontal distance between the center of bar mass and CM of the body at the instant the bar left the platform. This means that the greater-skilled lifters held the bar closer to them at this instant of time, which further emphasizes that the greater-skilled lifters were at a better leverage position to initiate movement of the bar and to execute the lift.

The post hoc t-test showed that the greater-skilled group took less time from the instant the bar left the platform to the instant the bar reached knee level. Probably, the greater-skilled group was at a better leverage position reflected by less trunk flexion, less knee extension, and less horizontal distance between CM of the bar and their CM. This allowed greater-skilled lifters to create more momentum between the two instances analyzed, which in turn explains why less time was taken to go between the two instances.
CHAPTER V

SUMMARY and CONCLUSIONS

The performances of ten powerlifters, five greater-skilled and five lesser-skilled, doing the deadlift were analyzed in this study. Each lifter was filmed while performing two trials of the deadlift. The films were digitized and several kinematic variables were measured for analysis. The purpose was to make a kinematic model of the greater-skilled lifters so that it could be used as a teaching tool when training other powerlifters.

Discussion of Hypotheses

Six hypotheses were formulated concerning the techniques used by the two groups. The following section discusses each hypothesis which compares the greater-skilled group to the lesser-skilled group.

$H_1$: The greater-skilled lifters use less trunk flexion from the instant of initial trunk lean to the instant of max trunk lean.

• This hypothesis was supported.

$H_2$: Greater-skilled lifters use less knee extension from the instant of initial trunk lean to the instant of max trunk lean.

• This hypothesis was supported.
**H₃**: Greater-skilled lifters use less of a trunk angle at the instant when the bar is at knee level.
- This hypothesis was not supported.

**H₄**: Greater-skilled lifters use less thoracic lean relative to trunk lean at the instant the bar is at knee level.
- This hypothesis was not supported; however, a trend was noted that greater-skilled did have less lean when compared with lesser-skilled.

**H₅**: Greater-skilled lifters demonstrate a smaller horizontal distance between the body CM and the CM of the bar at the instant when the bar leaves the platform.
- This hypothesis was supported.

**H₆**: Greater-skilled lifters demonstrate a smaller horizontal distance between the body CM and the CM of the bar at the instant when the bar reaches knee level.
- This hypothesis was not supported.

**Conclusions**

Based on the results of this study the following conclusions are drawn:

1. Greater-skilled powerlifters in the deadlift use less trunk flexion than lesser-skilled lifters when the initial trunk lean is compared to max trunk lean. This seems to occur because greater-skilled lifters possess stronger musculature in the trunk region.

2. Greater-skilled lifters show less knee extension from the
time of initial trunk lean to max trunk lean than the lesser-skilled lifters, thereby enabling them to utilize more hip leverage for the completion of the lift.

3. Greater-skilled lifters demonstrate less horizontal distance between their CM and bar CM at the time the bar leaves the platform. This enables them to have better leverage for the execution of the deadlift.

4. Greater-skilled lifters take less time to get the bar from the platform to the knee level, thereby enabling the bar to have more upward momentum to complete the lift.

Recommendations for Further Study

If this study is replicated, the following procedural changes might help in reaching stronger conclusions:

1. Increase the number of subjects. A study held at a meet site would be more difficult to organize, but would provide more subjects.

2. Use other analytical techniques involving the thoracic region to further determine thoracic lean differences. Perhaps a way could be found to attach sticks to the mid line of the back, where musculature will not have an effect.

3. Find a means of determining amount of thoracic lean flexibility, so as to determine if it is a factor in the amount of thoracic lean during the execution of the deadlift.

The results of this study illustrate that there are many open areas for research in the sport of powerlifting. Hopefully this
study sheds some light on some of the technique problems that lesser-skilled lifters may develop, and that it may be of some help in overcoming them.
APPENDIX A
MEANS, STANDARD DEVIATIONS AND $t$ SCORES FOR THE TWO GROUPS.

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<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>.13</td>
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</tr>
<tr>
<td>$M$</td>
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<td>23.2</td>
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<td>143.2</td>
<td>28.42</td>
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<td>.95</td>
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<tr>
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<td>.038</td>
<td>2.73*</td>
<td>.067</td>
<td>2.45*</td>
</tr>
</tbody>
</table>

* $t$ score is significant at .05 level of significance. Probability level at .05 level of significance = 2.31

$1$-test

1. Trunk flexion angular displacement from instant of initial trunk lean to the instant of max trunk lean.

2. Knee extension angular displacement from the instant of initial trunk lean to the instant of max trunk lean.

3. Difference of angles between thoracic lean and trunk lean at the instant the bar is at knee level.

4. Trunk angle at the instant the bar is at knee level.

5. Horizontal distance between CM of the bar and CM of the subject at the instant the bar leaves the floor.

6. Horizontal distance between CM of the bar and CM of the subject at the instant the bar is at knee level.

7. Time between the instant the bar left the platform to the instant the bar reached knee level.
APPENDIX B
USE OF HUMAN SUBJECTS

INFORMED CONSENT

NAME OF SUBJECT ________________________________

1. I hereby give consent to ________________________________
   to perform or supervise the following investigational procedure
   or treatment:

   Two-one repetition trials of the Deadlift.

2. I have (seen, heard) a clear explanation and understand the
   nature and procedure or treatment; possible appropriate
   alternative procedures that would be advantageous to me (him,
   her); and the attendant discomforts or risks involved and the
   possibility of complications which might arise. I have (seen,
   heard) a clear explanation and understand the benefits to be
   expected. I understand that the procedure or treatment to be
   performed is investigational and that I may withdraw my
   consent for my (his, her) status. With my understanding of
   this, having received this information and satisfactory answers
   to the questions I have asked, I voluntarily consent to the
   procedure or treatment designated in Paragraph 1 above.

   ________________________________
   Date

   SIGNED: ___________________________ SIGNED: ___________________________
   WITNESS                          SUBJECT or

   SIGNED: ___________________________ SIGNED: ___________________________
   WITNESS                          PERSON RESPONSIBLE

   ________________________________
   RELATIONSHIP

Instructions to persons authorized to sign:
If the subject is not competent, the persons responsible shall be the
legal appointed guardian or legally authorized representative.
If the subject is a minor under 18 years of age, the person
responsible is the mother or father or legally appointed guardian.
If the subject is unable to write his name, the following is legally
acceptable:
John H. (His X Mark) Doe and two (2) witnesses.
REFERENCES


