Original Research

Variation in Barbell Position Relative to Shoulder and Foot Anatomical Landmarks Alters Movement Efficiency

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ABSTRACT

International Journal of Exercise Science 5(3) : 183-195, 2012. The purpose of this study was to determine if either of the two deadlift starting positions would yield a more efficient movement than the other; (1) the traditional Olympic lifting and deadlift starting position with the barbell over the metatarsalphalangeal joint and under the acromioclavicular joint or (2) an experimental alignment with the bar over the navicular bone and under the most inferior and medial aspect of the scapular spine. This second starting position, developed as a teaching convention, differs from the historical alignment of toes-barbell-shoulder joint and is also proposed to reduce horizontal displacement of the bar thus minimizing the amount of work needed to complete the movement. It was hypothesized that the experimental alignment would produce a more efficient pulling movement compared to a traditional starting alignment. Efficiency was defined as a barbell path approaching linear movement, with larger horizontal displacements being considered less efficient than smaller displacements. Six intermediate level weightlifters, 23.8 ± 1.9 years of age, 164.7 ± 7.9 cm in height, 81.5 ± 31.9 kg in body mass, completed a series of deadlifts under both alignment conditions with 90% of their self-reported 1RM (169.0 ± 58.17 kg). Posterior horizontal barbell displacement was measured by video-analysis. In the traditional alignment (metatarsalphalangeal-bar-acromioclavicular) displacement was 66.7 ± 12.9 mm and was 37.5 ± 13.7 mm in the experiment alignment (navicular-bar-scapular spine). The noted 43.8% reduction (29.2 mm) in horizontal displacement in the experimental alignment condition was statistically significant ($p = 0.0001$) and supports the hypothesis in regards to improved lifting efficiency.

KEY WORDS: Strength performance, weight training, exercise anatomy

INTRODUCTION

Strong men have competed in informal and formal competition throughout history and this has been well documented in archaeological and historical records. While depictions and cursory references to men lifting objects in competition are quite meaningful, descriptions of the human movements used to lift implements or weights has not been a consistent feature of available literature. In essence, a critical analysis and resultant description of the elements of proper lifting technique is missing. It is likely that this pedagogic and scientific omission is a product of competition format, as historically whomever successfully raised the heaviest weight over head by any means won. This approach to lifting technique and competition became problematic at the 1896 Olympics, the first modern Olympic Games. In that competition, Launceston Elliot of Scotland and Viggo Jensen of Denmark tied for first place by lifting the same weight in a two-handed lift, 110 kg. At the time there were no uniform rules in place regarding the techniques to be used in competition. As a result of the tie, the observing official, the Crown Prince of Greece, ruled that Jensen had lifted the weight in a better style and was thus awarded the gold medal. This was later protested by the Scottish contingent on the grounds that no documentation was present as to what was considered a “better style”. The appeal by the Scots was unsuccessful (3).

Shortly after the first Olympic games, a governing body, the International Weightlifting Federation (IWF) was created to oversee and regulate the sport of weightlifting (17). From its creation in 1905 until the present day, the IWF develops and enforces the technical rules for the sport, contested in and between 167 affiliated nations. To prevent occurrences similar to the 1896 tie, the IWF created a set of competitive rules and regulations for each competitive lift. At the beginning these rules were broadly constructed as there were many different lifts included in Olympic competition, both dumbbell based and barbell based. Eventually the menu of lifts were narrowed to three barbell lifts that all began with the weight on the floor and finished with the weight overhead, the press, the snatch, and the clean & jerk. Each lift was discriminated from the others by the technique in which it was completed. The press consisted of pulling the bar up onto the shoulders followed by a second movement where the shoulders and elbows were extended thus raising the weight overhead. The snatch was a single movement lift requiring the weight to be pulled from the floor up to completely extended arms overhead. The clean & jerk, as its name implies, is a two movement lift. In the first movement, the barbell is pulled to the shoulders, as in the first movement of the press, this is the "clean" portion. In the jerk, the knees and hips are used to produce a very rapid and shallow squat and extension that propels the barbell overhead where it is caught on extended shoulders and elbows.

It is at this point in history that the evolution of the problem addressed in this project begins. The official rules regarding all three lifts prohibited touching of the bar against any part of the body except for the hands that grasped it and the shoulders on which the bar transiently rested upon in the press and clean & jerk (1). The rules specific to the pulling of the bar from the floor disallowing any contact with the body was a limitation in performance. Elementary physics mandates that the mass of the barbell will move towards the center of mass of the body supporting it, to a point where the combined center of mass (barbell and human) is supported over a point midway between its most anterior and posterior points of support. Because of the prohibition of thigh-bar contact, the position a lifter of the era would assume relative to the bar was to place the toes (phalanges) or the ball of the foot (metatarsal-phalangeal joint) directly under the bar. This made the distance the bar had to cover before it touched the legs the maximum possible. Any more of a forward displacement (beyond the toes) significantly reduces the efficiency of the operating lever arms to a point that only lighter weights can be lifted.

Another part of the bar-thigh touch solution of the time was in joint movement sequence. Under the early and mid-twentieth century rules, the actual pulling motion used by lifters consisted of nearly simultaneous knee and hip extension. The combination of a bar-forward starting position and simultaneous joint extension set up a shallow forward arc in barbell path that prevented the bar from coming in contact with the thighs.

As the quest to lift more and more weight continued, the rules were softened or evolved. By the mid-1960's, it had become legal for the bar to come in contact with the shins and the thighs. This provided a performance advantage as the barbell's mass could now be placed in a more favorable position in order to apply more muscular force to it. An interesting thing happened in regards to lifting technique, or rather did not happen that may have limited further increased lifting performance. Instead of modifying the bar-foot spatial relationship at the start of the lift to reflect a more efficient technique, efficiency defined as movement approaching a straight line, weightlifting coaches continued to, and still to this day, teach a bar over toes and shoulder joint over the bar starting position that was appropriate in the first half of the twentieth century (6). A start position that is known to induce rearward horizontal displacement during the initial pulling movement from the floor.

A perusal of the literature relevant to the pulling motion in weightlifting demonstrates a very limited research pool. Virtually all published accounts of pulling research focus on the path the bar takes during Olympic style weightlifting without consideration of the anatomical construction and physical relationships of the body that is lifting it. Only a few papers consider the pulling lift examined here, the Deadlift, in any manner (5, 9,14). Although the dearth of literature in regards to the topic is perplexing, it is understandable. There is no history of weightlifting performance research being supported by grants from governmental or private funding agencies, as strength and sport performance have been historically thought to be irrelevant to most health and commercial research enterprises, or at least thought to be less important than endurance and thus less fundable.

It was not until 2007 that a consideration of combined human anatomy, physics, and pulling a barbell off of the floor received even cursory attention. In the second edition of the book Starting Strength (15), a conceptual framework was proposed for an association existing between the foot, the bar, and the scapula in any pulling motion off of the floor. Originally conceived as a method of teaching reliable, repeatable, and efficient pulling technique, the scapular alignment model the authors proposed intended to both normalize teaching methods and to improve the efficiency and performance in the deadlift. The cornerstone of the teaching technique was placing the bar over the mid-foot and under the middle of the scapular spine, a straight line connecting the three points. This starting position, which differed from the historical alignment of toes-barbell-shoulder joint, is proposed to reduce horizontal displacement of the bar (make the bar path more closely approximate a straight line), thus minimizing the amount of work needed to complete the movement. Use of the alignment was suggested to reduce the amount of extraneous muscular work done which did not contribute directly to lifting the barbell. In concept, this improved efficiency might make the deadlift more reproducible between repetitions and allow more weight to be moved by the lifter. The usage of the term efficiency here, movement of a body or an implement that approaches a straight line, is the same as in previous literature (7, 22).

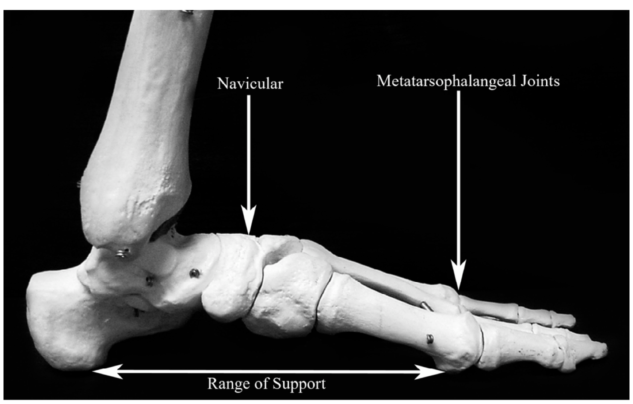

Figure 1. The navicular bone represents the mid-point of the base of support for the foot and in the scapular alignment model is the point above which the barbell is placed at the beginning of a pull.

In the scapular alignment model it is further proposed that this anatomical alignment and its benefits could be applied to the pulling components of the Olympic lifts as other authors have suggested the start positions and pulling motions to be nearly identical among the three lifts (9, 19). This model was further investigated to determine the point on the scapula under which the barbell was suspended (11). In that study, the bar was positioned over the navicular bone as the anatomical landmark for the "mid-foot" placement described within the theory (figure 1) and then the location where the bar was suspended during lifting from the floor was localized. It was determined that the barbell assumed a position under the most inferior and medial aspect of the scapular spine (figure 2).

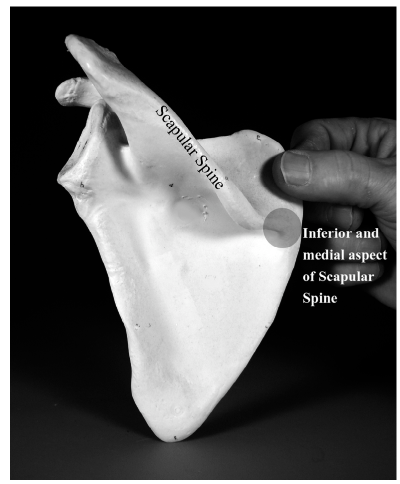

Figure 2. The scapular spine runs across the posterior surface of the scapula. The barbell, in any system of pulling, will become suspended under the most inferior and medial aspect of the spine.

Differences in anthropometric structure between individuals requires consideration in lifting exercises. Some anthropometric measurements, longer than normal arms for example, may predispose someone to being better at a pulling movement regardless of the technique used for the pull. In the case of longer than average arms, this reduces the vertical displacement the barbell must travel to deadlift completion and the resultant hip, knee, and ankle lever angles at the start of the lift are more open and mechanically advantageous than that of a shorter armed individual. Although there is no data to support this conjecture, the scapular alignment model is assumed to produce optimal joint angles and movement efficiency across all anthropometric variations.

The deadlift is a competitive powerlifting event and is the simplest of the pulling movements with a barbell. In the deadlift, the barbell is lifted from the floor until the knees, hips, and shoulders are locked out (normal anatomical extension is assumed). All competitive lifts currently contested in the Olympic Games, the snatch and the clean & jerk, include essentially the same movement in their initial stages. So for all sports that utilize a pulling motion off of the floor as an event or portion of an event, an understanding of how to most efficiently perform the movement is critical to success and safety. But pulling motions are not solely the realm of competitive strong men. Each of the exercises described so far are commonly used in strength and conditioning programs for virtually all sports and they are used in fitness programs for the general population.

However, it is occasionally a source of injury from being performed improperly or it is entirely left out of strength programs because of the inability of coaches to teach it correctly or because it is a very hard lift by virtue of the amount of weight that can be used (15, 18, 21). Therefore, it is warranted to determine if the anatomical positioning proposed for the starting position as suggested in the scapular alignment model of teaching the deadlift is any more or less efficient than the historical starting position.

There is a tremendous void in the literature evaluating anatomical orientations of the body and their effects on any barbell exercise performance. All previous research has involved observation and characterization of native subject technique and has not manipulated body position. The purpose of this study was to determine if two different anatomical orientations relative to a barbell altered movement efficiency during the deadlift. Specifically it was of interest to evaluate how the traditionally used starting position, the bar over the metatarsal-phalangeal joints and under the acromioclavicular joint, compared to the bar path following alignment of the bar over the navicular bone and under the inferior and medial aspect of the scapula. The present study provides data that represents a first step in such an undertaking by examining the effects of two different anatomical orientations on pulling efficiency in the deadlift. The data herein will assist in moving the teaching of weighted exercise forward by enabling objective explanation of why an exercise is executed with a specific technique, rather than the historically limited, arbitrary, and subjective approach ("we've always done it this way") presently in practice. It was conjectured that, in the deadlift, a starting position with the bar directly over the navicular and directly under the most inferior and medial aspect of the scapular spine would produce a more efficient (linear) pulling movement compared to a starting position with the bar over the metatarsophalangeal joint and under the acromioclavicular joint.

METHODS

Participants

Six intermediate level competitive weightlifters (4 male and 2 female) between the ages of 18 and 30 years of age volunteered for the study. All participants gave informed consent for participation in the experiment. The project was reviewed and approved by the Midwestern State University Human Subjects in Research Committee.

Protocol

In order to examine the potential effects, an experiment was conducted comparing two anatomical alignments of the body in relation to the barbell during execution of the deadlift exercise. The two specified start position alignments were: (A) alignment of acromioclavicular joint, bar, and metatarsophalangeal joint, the historically adopted start position, and an experimental start position where (B) alignment of the scapular spine, bar, and navicular (figure 3). Data was collected by high speed video that was manually digitized for analysis of bar movement for efficiency.

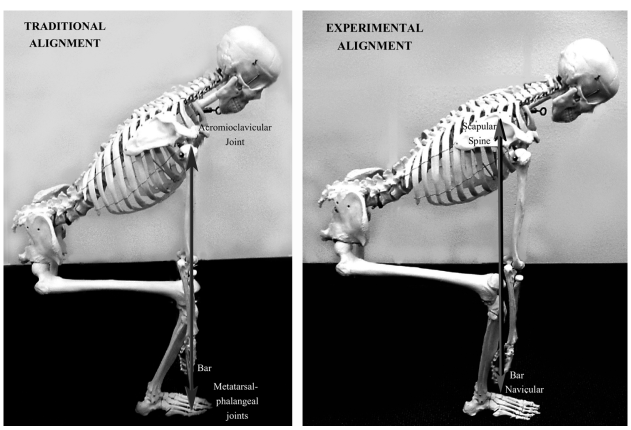

Figure 3. The traditional alignment (left) has the bar over the metatarsal phalangeal joint and under the acromioclavicular joint. The experimental alignment (right) has the bar over the navicular and under the inferior and medial scapular spine.

Deadlift Procedure: A York International Standard Olympic barbell was placed on a platform loaded with 90% of the self-reported 1RM (in kg) for each subject. A strip of marker tape was oriented parallel and directly beneath the bar. The tape spanned the width of the platform and was used as a marker for precise anatomical alignments of the feet. The high speed video camera was placed, leveled, and aligned to the right side (from the subjects view) of the barbell - the field of view of the camera was perpendicular to the barbell and the marking tape. This orientation allowed for detection of any bar displacement in the anterior-posterior plane. Prior to filming the first subject, the vertical dimension of the field of view was set so that the maximum height of the tallest subject was accommodated and was unchanged for the duration of the study so that the scale of the video would not differ between subjects.

Prior to data collection, each subject went through four sets of deadlifts as a warm-up. All warm-up weights were calculated as a percentage of 90% of their 1RM deadlift. The first warm-up set was 5 repetitions with 30%, the second set was 3 repetitions at 50%, the third set was 3 repetitions at 65%, and finally a single repetition was done at 80%. For example a reported 150 kg 1RM would require a warm-up with 45kg for 5 repetitions, 75kg for 3 repetitions, 97.5kg for 3 repetitions, and finally a single repetition with 120kg.

To ensure that foot placement conditions were identical across subjects, the participants were placed in appropriately sized Dynamo weightlifting shoes (VS Athletics, San Luis Obispo, CA). Prior to lacing the shoe, the navicular bone and metatarsalphalangeal joints were palpated and their positions were marked on the top and side of the shoe with tape. The subject then approached the platform and barbell loaded with 90% of their 1RM deadlift. The two anatomical alignments were randomly ordered between subjects. To place a subject in a correct alignment they were first instructed to place the appropriate shoe marking tape (navicular or metatarsophalangeal joint) directly over the floor marking tape. They were allowed to use their otherwise normal stance. Subjects were then coached into the correct shoulder alignment position. For the traditional deadlift start position, subjects were allowed to assume their "normal" start position and were then adjusted to ensure that the acromioclavicular joint was above the bar. For the experimental start position the subjects were first crudely positioned by coaching them to a position where the axillary crease was over the bar and then they were quickly palpated to confirm the position of the inferior and medial aspect of the scapula. All alignments were confirmed by the researcher before for each of two trials at 90% of 1RM deadlift. Upon completion of the two trials in the first assigned alignment, the subject then proceeded to the second alignment. A three minute break between each set was enforced in order for the participant to completely recover to ensure similar preparation for each trial, and to provide researchers the time to realign the barbell with the floor marking tape, and other data acquisition organizational tasks.

Measures
Prior to experimentation subject descriptive data was collected; age (yr), height (cm), shoe size (US scale), weight (kg) and self-reported current 1 RM in the Deadlift (kg).

Video data for use in displacement analysis was acquired with a Canon FS31 A/FS300 camera (Canon, Lake Success, NY) shooting at 60 frames per second. The camera was placed 3 meters from the end of the bar on a tripod with the lense at a height of 1 meter. The field of view was oriented to precisely align with the direction of the bar (looking at the proximal bar end). An Image Mixer 3 SE transfer utility (Pixela Corporation, Osaka, Japan) was used to transfer the video to a computer. A Pixela Application Image Mixer 3 SE video tool (Pixela Corporation, Osaka, Japan) was used for editing of the raw video data to remove non-data segments and also used for playback during the digitization process.

A bar tracing was produced for each lift to determine the displacement of the bar during the Deadlift. A 4x4 mm grid on clear acetate was placed over the digital image. Scaling of the grid was set for 4 mm on the digital video image being equal to 50 mm of body or barbell movement. The original start position of the bar on the platform served as the anchor source of the vertical axis from which displacements were measured. The path of the barbell end (center point of the bar – identified on each frame), from the floor to lockout, was manually plotted on the grid, measured in millimeters relative to the greatest horizontal excursion from the original vertical axis, then the data entered into a Microsoft Excel™ (Microsoft, Seattle, WA) spreadsheet for later statistical analysis and transfer into a line graphs for visual representation of bar path.

Statistical Analysis
The nature of the experiments dictated the use of a simple paired Student's T-Test evaluating the probability that any differences in horizontal displacement noted between anatomical alignment conditions were not simple random chance.

Basic subject characteristic descriptive statistics were completed using Microsoft Excel™ (Microsoft, Seattle, WA). Experimental data was analyzed using Statistica statistical software (StatSoft™, Tulsa, OK). Statistical significance was set *a priori* at ≤0.05.

RESULTS

The mean age of the subjects of this study was 23.8 ± 1.9 years. The average height was 164.7 ± 7.9 cm and their weight was 81.5 ± 31.9 kg. The heaviest subject weighed 143.2 kg, the smallest subject weighed 57.5 kg thus there was a spectrum of body dimensions present in the subject pool. As pre-testing of subjects to determine 1RM deadlift was not possible given the schedule available for the research, self reported 1RM weights were used. The mean for all subjects was 169.0 ± 58.17 kg. This weight places the subjects in the intermediate stratification in published strength standards for the deadlift (12).

Bar trajectories with orientation of the bar to the foot are shown in figure 4. Although there was considerable displacement of the bar to the posterior with both anatomical alignments, simple visual inspection of the individual subject figures demonstrate that the magnitude of the displacement was far smaller with the experimental, navicular-bar-scapular spine, orientation than with the traditional bar-forward start position.

The actual displacement data bears out the visual impression of smaller displacements with the experimental foot-bar-shoulder alignment. The mean bar displacement was nearly double in the traditional start position compared to the experimental start position, 66.7 cm compared to 37.7 cm (table 1, figure 5). Statistical analysis, a T-test for dependent samples, demonstrated a strongly significant difference between the two tested anatomical alignments, with a p = 0.0001. This strongly suggests that use of the navicular-bar-scapular spine alignment at the starting position directly results in less horizontal displacement than the traditional metatarsophalangeal-bar-acromioclavicular alignment.

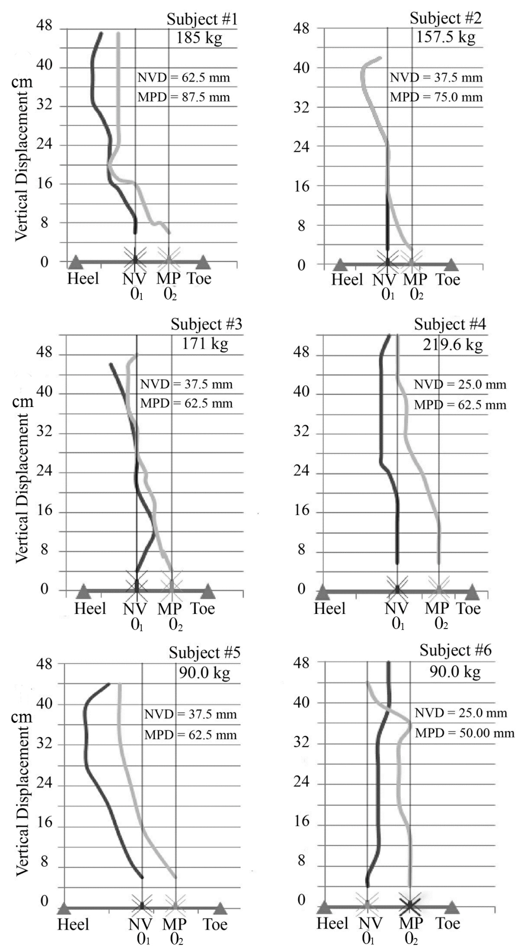

Figure 4. Individual subject bar paths and displacement data for both tested anatomical alignments. NV = navicular bone; MP = metatarsalphalangeal joint; NVD = displacement in experimental alignment; MPD = displacement in the traditional alignment. 0_1 starting point and vertical axis of experimental alignment, 0_2 starting point and vertical axis of traditional alignment. Note: Subject #2, above 24 cm the trajectories are coincident.

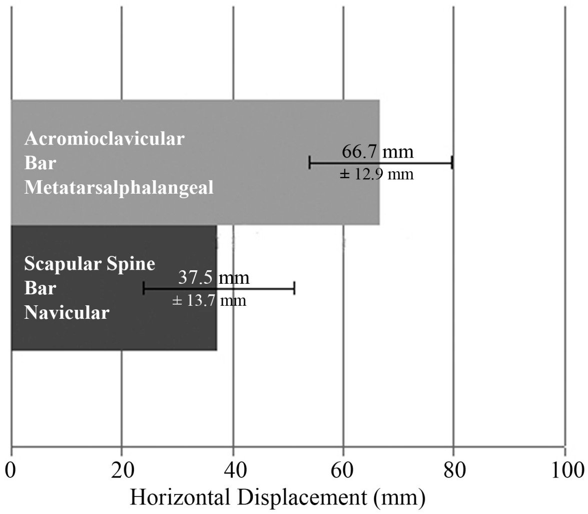

Figure 5. Horizontal barbell displacements by group.

Alignment	Mean	SD	Diff.	t	p
Navicular	37.5	13.7			
Metatarso-phalangeal	66.7	12.9	-29.2	-11.1	0.0001

Table 1. Results for horizontal displacement measures and statistical analysis for the two anatomical alignments tested.

DISCUSSION

The central purpose of this experiment was to explore whether an anatomical alignment of the bar above the navicular and the bar below the inferior medial aspect of the scapular spine at the start of the deadlift would produce a more linear, thus mechanically efficient, pulling movement compared to a starting position with the bar over the metatarsophalangeal joint and under the acromioclavicular joint.

The physical concept of efficiency is reflected in the commonly used idiom, "the shortest distance between two points is a straight line." Similarly, and consistent with basic physical law, the definition of efficiency used here was movement approaching a straight line. The hypothesis was supported by the data of the present project as mean maximal horizontal displacement in the experimental starting position with the bar over the navicular averaged 29.2 mm less horizontal deviation than when the bar was placed over the metatarsalphalangeal joints, the traditional starting position. This 43.8% reduction represents a more efficient movement pattern and suggests that this novel anatomical alignment of the body relative to the barbell is a superior technique in the performance of the deadlift. When comparing the displacement data from the present study to those of Garhammer (7) and Vassilios, et al. (20), those displacements produced using the traditional start position, with the bar of the metatarsal phalangeal joints, the results were quite similar. Garhammer's paper reported a range of horizontal displacements between 30 to 90 mm to the posterior in weightlifters in competition. Vassilios and co-workers reported a mean posterior displacement of 62.0 ± 22.3 mm in their paper. The mean displacement noted here, 66.7 ± 12.9 mm, lends credibility to the present study as effectively creating a valid reference condition relevant to the most commonly used starting position in lifts that include pulling motions from the floor.

To our knowledge, this paper is the first to prospectively examine the effects of anatomical position variations at the start position on weighted movement patterns. Although the hypothesis forwarded was found to be accurate, further data must be collected across all training populations and across all exercises intensities in order to confirm these findings. Further, the present study analyzed the deadlift, thus the scope of the research is rather narrow and might not be completely generalizeable to all weighted motions with pulling components. Specific to weight sports, future research is needed to determine the applicability of these data to the clean and snatch movements.

The subjects in this study were intermediate to advanced weightlifters (the Olympic sport) and were not accustomed to the deadlift as a training tool or as a competitive lift. As such, although they stated competency, experience, and a kilogram value they could lift as a maximum, it is likely that the self-reported 1RM values were not accurate. It was apparent from observation of the subjects during testing that the values they gave, that were intended to calculate a submaximal experimental weight of 90% of 1RM, were not accurate. All subjects struggled to complete two repetitions per set, with one subject unable to lift his estimated 90% for a second repetition. Four of the six subjects exhibited form breaks manifesting as visible anterior vertebral flexion at the thoracic level, lumbar level, or both as the bar neared or passed the level of the knee. Proper technique in the deadlift requires the vertebral column to be held in normal extension throughout the lift. Failure to do so induces artifactual and undesirable barbell displacements. This was observed in these subjects. In retrospect, a pre-test determining actual 1RM deadlift would have been desirable in prevention of this issue. Although the failure of the subjects to maintain proper technique throughout the experiment prohibited a true evaluation of the potential to produce a clearly linear bar path, the magnitude of difference between the two experimental conditions remains strong evidence of the more linear bar path produced by the navicular bone alignment in the start position.

The utility of these findings is further supported by the work of Hakkinen, Kauhanen & Komi (10) who investigated the effect of increasing load on selected mechanical aspects of lifting technique. They were interested in this as exercises included in training programs in preparation for competition are by and large done with submaximal loads, less than 100% 1RM. However, during competition the lifts are performed with maximal loads. Their data indicated that some of the kinetic parameters of technique, such as velocity of barbell movement, was significantly altered by the load (percent of 1RM). This relationship was found for both novice and elite lifters. In their summary it was suggested that further experimentation be done in this area with both submaximal and maximal loads.

Campos and associates (4) found that weight classes did not affect the pattern of bar path, however they suggested that athletes in the heavier weight categories were more efficient. But unlike the physics based definition utilized in the present research, they defined efficiency as force exerted on the barbell during the initial lift-off phase for a relatively longer duration, the longer duration purportedly corresponding to a more strength-oriented action. This seems a rather weak definition as it is well known that as weight lifted increases, the velocity of barbell movement slows (10). The question remains as to whether heavier lifters lifting very heavy loads are more likely to produce closely linear bar paths. This question has not been satisfactorily addressed in the literature.

Three of the six subjects in this study showed a tendency to pull the bar, let it swing, or were compelled by physical forces acting on the bar to allow displacement, to the rear of the navicular at some point during the lifting motion. All of the subjects included in this study were coached by a USA Senior International Weightlifting Coach and had been strongly conditioned to shift the center of pressure on the foot from the ball of the foot or toes, back to the heel, and then back forward to the ball of the foot during the pulling motion. This concept of weight shift is represented in the weightlifting literature in the works of Garhammer (7) and Takano (19). Both papers lead one to believe that shifting of balance from the metatarsal region to the front of the heels is a coachable and desirable pattern of movement. The authors further proposed that due to the mass of the barbell tending to be one to three times the body mass of the athlete, the combined systems center of pressure on the feet was necessarily associated with forward and backward movements of the bar during pulling motions. Neither paper considered the actions of the bar through space to be affected by the anatomical system that was moving it, rather they conceived that the mass of the barbell dictated the movement of the anatomical system. Regardless, the subjects in the present study were strongly conditioned to produce this movement pattern and may have unconsciously attempted to move in the same pattern under both anatomical alignments.

The importance of limiting displacement of the barbell in competitive lifting success is presented in a paper by Gourgoulis et al. (8), where comparison of successful versus unsuccessful lifts with the same weights by the same athlete was done. The researchers noted that general movement pattern did not change between successful and unsuccessful lifts rather the difference resided in the direction of the force vector in the pull off of the floor. This corresponds somewhat to the findings of Schilling and co-workers (16) who found that displacement of the body (forward displacement, no displacement, rearward displacement) did not affect success rate. These researchers only examined foot displacement and suggested that the entire body should be evaluated in order to determine the cause of the rearward foot displacement.

The tendency for rearward displacement of the bar towards the body has been discussed for decades. Baumann and his research group (2) noted that that the pathway of the barbell during lifting (specifically Olympic weightlifting) has undoubtedly changed, with the bar coming more toward the lifter during the initial pull off of the floor. They followed up with the statement that, as a consequence of the initial rearward displacement, there must be a backward jump during the drop under the barbell. Although there has been no systematic experimentation with alternative techniques, and as a large number of elite international lifters display a rearward displacement it is considered a preferred occurrence and is recommended to coaches and athletes as a movement pattern that should be mimicked (16).

There was no hard evidence found as to the absolute origin of the traditional bar orientation to over the metatarsophalangeal joints and its subsequent rearward displacement during lifting from the floor, only anecdotes from historical figures and rule documents. Further, the traditional start position was originally specific to the Olympic lifts the snatch and clean & jerk. It is not known how this start position made its way into the coaching of the deadlift start position, other than in the early days of powerlifting, it was common for athletes to compete in both sports and coaches to coach in both sports.

While it is possible that some gifted athletes with specific anthropometric characteristics have assumed the use of the traditional start position alignment and the resulting posterior barbell displacement naturally, it is much more likely that it is a taught concept, position, and result. There is no comparative data regarding different pulling techniques. Whatever the reason for adoption, the majority of weightlifters and powerlifters follow convention and tradition and assume the bar over forefoot position as a start position. And as the majority of lifters use the position, it is assumed by athletes, coaches, and sport scientists to be the optimal and best position even to the point of ignoring basic laws of physics. It is a common argument for following convention that a lifter who uses the traditional start position has set a world record or won a major championship, so obviously the technique must be optimal. It is a much more relevant sentiment that we should be less concerned with the way something has always been done and more concerned how we can do it better.

In summary while there is a defined improvement in movement efficiency by using a navicular-bar-scapular spine alignment at the start of a deadlift, further exploration into this model needs to be conducted. If the findings here are borne out by future researchers, coaches will benefit by having an objective and data based means of coaching pulling movements and athletes will be provided a potential means of rapid learning of technique and maximization of performance.

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