TABLE OF CONTEST

ABSTRACT

Purpose: The purpose of this study was to investigate the influence of barbell type on lifting technique and muscle and joint load during submaximal weights in deadlift. **Method:** Barbells from olympic weightlifting (OWL) and power lifting (PL) were used. Sixteen subjects from different strength disciplines executed twelve submaximal lifts at minimum 150 kg. Electromyography, force plate and ProReflex were used to collect data about muscle activity, force production, moment on joint and barbell trajectory. **Results:** Shows significantly differences in barbell qualities between the OWL and PL (71574 ± 4611 vs. 85502 ± 9818, $p < 0,05$). One EMG measurements were found to be significant, m. vastus medialis (holdsteady) (65 ± 37 vs. 57 ± 36, $p< 0,05$). One EMG measurement were a trend, m. longissimus (earlystart) (243 ± 129 vs. 255 ± 125, p 0,059). Sixteen EMG measurements were non significant. No significant moment differences on joints were found, such as the pelvis (holdsteady) (392 ± 136 vs. 390 ± 141, p 0,914) and the knee (maxmoment) (384 ± 141 vs. 384 ± 130, p 0,995). Other measurements such as rate of force development (RFD), barbell trajectories and maximal force (MaxFz) were non significant. **Conclusion:** The results indicate that the barbell choice when executing a submaximal deadlift has no effect on physical load or technique.

INTRODUCTION

Olympic weightlifting was one of the first sports on the schedule at the olympic games in 1896. OWL consists of two whole body exercises, the snatch and the clean & jerk (C&J) (iwf.net, 2013). Characteristics of OWL is exactly this two overhead lifts. In training the focus is on heavy load in support exercises and moderate loads but explosive velocity/movement during the snatch and C&J (Mcbride et al., 1993). In Powerlifting there are three exercises, the squat, the deadlift and the bench press (Powerlifting-ipf.com, 2013). The characteristics of PL are extremely high loads on the bar, which means maximal force production but slow velocity during the lifts. Still, powerlifting is an explosive sport, but because of the total load that has to be lifted, the residual motion after the lift off from the ground is at slow velocity (Mcbride et al., 1993). The technical regulations for OWL and PL are not relevant information and will not be further explained.

In both sports one must produce force to lift the barbell from the ground, the main work for the lifter is to overcome gravitational forces (the total load of the barbell). The OWL-barbell is known for its elastic qualities. It is generally acknowledged in the OWL and PL community that an OWL-barbell will provide a small boost with its fluctuations due to the elastic qualities. As a result, this allows the lifters to put on some extra kilos in exercises as squat, deadlift and clean pulls opposed to the PL-barbell. This effect is likely to decline the higher the load gets; due to the elasticity the OWL-barbell gets an increasing degree of instability at higher loads, in contrast to the PL-barbell that is made to handle more extreme weights. In PL the barbell is 1mm thicker in diameter but made from the same material as the OWL-barbell (product development manager, Eleiko, personal communication. Due to its 1 mm thicker diameter the PL-barbell generates more stiffness than the OWL-barbell. The barbells also have different coarser grip, sharper on the PL-barbell and softer on the OWL-barbell.

It is the exercise deadlift from PL that is the focus in this study. The deadlift is a multijoint resistance exercise, and one of the most practiced strength exercises in the world, probably due to its relative low requirements for execution the exercise. Deadlift may for some look quite similar to the first pull in C&J in OWL, but are many technical differences between those two movements. Such as different "lift-off" positions (angel on knee, hip and back), grip and stance width and especially how the lifters lift the barbell. OWL-lifters are known for using their thigh muscles more then their back, while PL-lifters are known for flexing their knees backwards immediately and use their back more (Refsnes, 2010). Still, according to Garhammer (1993) the "lift-off" position in deadlift and C&J can be comparable.

There is a great diversity of research on OWL and PL, they often focus on parts of the exercise, differences between them, power output, cross-over effect, athletic performance and barbell trajectory (Garhammer, 1980; Loren, 2007; Hales et al., 2009; Chulvi-Medrano et al., 2010; Stone et al., 2005). It does not appear that research have been done on which effect the two barbells could have on the same exercise or on the same movement pattern.

As briefly mentioned above, the OWL use a barbell that are elastic due to the explosive movements in their exercises and PL uses a barbell that are stiffer due to the heavy loads. Enormous forces are created and absorbed by the weightlifter when going under the barbell in the snatch and the C&J. Therefore it seems reasonable to have a barbell that can transport some of the forces trough the fluctuations in the barbell instead of impacting the lifter itself. Also several of the movement patterns in OWL are practically build around the fluctuations of the barbell, especially in the jerk. One can speculate if the idea behind these fluctuations of the barbell is to avoid or decrease the possibility of injury in OWL. The movements in each PL exercise are simpler then in OWL, all lifts are done at a slower velocity and in a controlled movement due to its heavier loads. Such fluctuations as in the OWL-barbell are therefore not necessary. It is probably rather preferred in PL to have a barbell that are more stabile and behaves like one with the lifter. It may as well be that such fluctuations in the barbell in PL will have opposite effect compared to OWL. Robert Wilks expresses himself like this:

> *"OLers value a springier bar, which will whip as the pull occurs & thereby accelerate the upward propulsion of the bar, whereas especially in the Squat & also the Bench Press the PLer values more stability in the bar, as any whip will be disorienting in those slower movements"* (personal communication, 2013).

According to the current world records in C&J and deadlift, respectively made by Hossein Reza Zadeh (263 kg) and Brad Gillingham (397,5 kg), a power lifter uses up to approximately 50 % more weights on the barbell (IWF, 2013; goodlift, 2013) and this added weight on the OWL-barbell will probably make the power lifter waste energy on stabilizing the OWL-barbell. *"...for similar reasons OLers want a bar that rotates quickly, esp. at the point where the bar spins or shifts in the hand as the lifter drops under the Clean or Snatch, whereas too much rotation can make a Deadlift fall out of your hand..."* Robert Wilks (personal communication, 2013).

These two barbells does not require different initial position before lift off, but at the moment you start the lift the successive positions during the lift can be different because of the various qualities of the barbells. Differences can also occur when the load of the barbell burdens the lifter in different time periods during the lift. In principal, it will take longer time before the weights have left the ground when using the OWL-barbell then the PL-barbell. This may create several differences visible and not visible to the eye when using the same load but different barbells because of the different successive positions (Wisnes, 2010). How much the barbells bend, and how much difference in stiffness it is between the barbells, are likely to be different depending of the total load on the barbell. Deadlift is used as a “model” movement, where submaximal lifts are chosen because of research issues that is the need for repetitions.

The aim of this study is to investigate the influence of barbell type (OWL and PL), on lifting technique and muscle and joint load during submaximal deadlift.

METHOD

Subjects & requirements

Table 1 shows the mean age and the mean 1RM in deadlift for the subjects.

	Mean
Age *(years)*	23,75
1 RM *(kg)*	220,9

The data were collected from 18 healthy men (self-reported) between 20 and 27 years. All subjects were from Sør-Trøndelag in Norway. They had to be member of an OWL, PL or a crossfit (CF) club. One subject did not meet these requirements, but with his PT background he was just as qualified as the others. This requirement was set to ensure that the subjects were familiar with the movement deadlift requires, and that they could perform the exercise in a proper and safe manner. Still, the variation of skill of the subjects was considerable, some have been permanent fixtures on the national team in OWL and in PL. Others were hard training men at a club level, whereas some of them were recreational hobby trainers. The subjects were asked to not train at maximal weights 48 hours before the study. Normal training was allowed.

Only men where chosen, this was done as a direct cause of the amount of women in Sør-Trøndelag that are members of an OWL, PL or CF club. Few women in Sør-Trøndelag hold the strength that this study requires. A minimum limit of a RAW (no PL-suit, no belt etc.) 1 RM was set to 180 kg in deadlift/clean pull to participate. The limit is set so the subjects can perform several deadlifts during the data collection at a minimum weight/percentage (150 kg or 75 %) that we consider is necessary for the measurements systems to find differences between the barbells. The weight the subjects had to lift was set to of minimum 150 kg, which is 75 % of 180 kg. It is preferable that all subjects would lift at 75 % of 1RM, but this was entirely up to the subjects themselves if they wanted 150 kg or more. Permission to conduct the study was given by the local ethical committee. All subjects signed a written voluntary consent to participation in the study.

Measurements equipment & facility

The kinematic data were collected with eight Qualisys ProReflex MCU 500Hz (Qualisys AB, Gothoenburg, Sweeden). EMG-activity was measured with Noraxon clinical direct transmission system EMG sensors and PC interface receiver (Noraxon inc, Greenway-Hayden Loop, USA.) The kinetic data were collected with one Kistler force plate (9286AA) (Kistler instrumente AG, Winterthur, Switzerland). Kistlers software BioWare was used for data acquisition of the force plate. New barbells from Eleiko were purchased (Eleiko sport AB, Halmstad, Sweden) for the study. Engineering special produced ProReflex clamps (NTNU, Trondheim, Norway) were used to mount the ProReflex markers on the barbells. Timing the pauses was done with a Gymboss timer (Gymboss, St. Clair, USA). Analysis took part in Matlab vR2013a (The MathWorks Inc, Massachusetts, USA), Excel v2010 (Microsoft inc, Redmond ,USA) and in Qualisys Track Manager (QTM) (Qualisys AB, Gothoenburg, Sweeden).

Calibrations of the cameras were done before each day of data collection, according to manufactures recommendation. Nine ProReflex markers were placed on the barbell (see figure 1 & 2) to measure barbell bending, barbells trajectory and time periods during the lift. Six ProReflex markers were also placed on six joints of the subjects, to measure joint position and moment during the lift. Six EMG electrodes were placed on six muscles on the subjects to measure muscle activity during the lift. EMG-electrodes were positioned according to SENIAM recommendations (Hermens et.al, 1999). Kistlers force plate was recording at 100 Hz, while the cameras were capturing at 100 frames per second and EMG at 1500 Hz. QTM gathered data samples from cameras and EMG and data from force plate were collected with Bioware, but a trigger coordinated all three systems. Each recording were set to 25 seconds, which means that the calibration of baseline, measuring the subjects bodyweight and executing the lift are included in these 25 seconds.

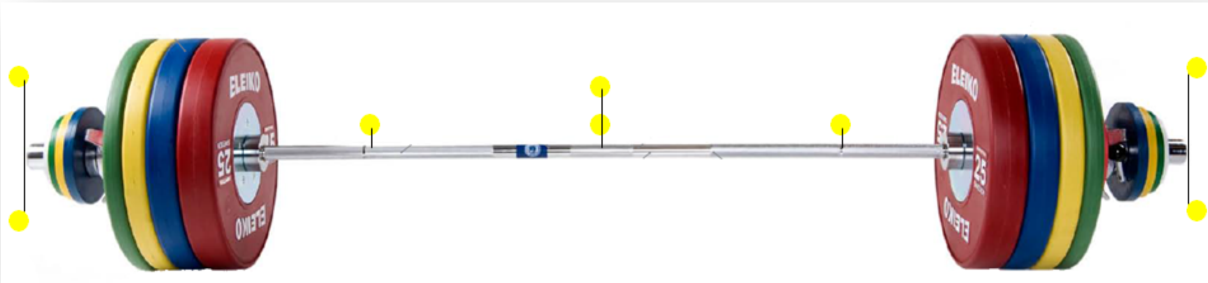

Figure 1 - ProReflex markers placement on barbell. Two markers were used at the ends and middle. This setup allowed the calculation of the centre of the barbell at 5 point along its length. Picture obtained from Eleiko AS product catalogue.

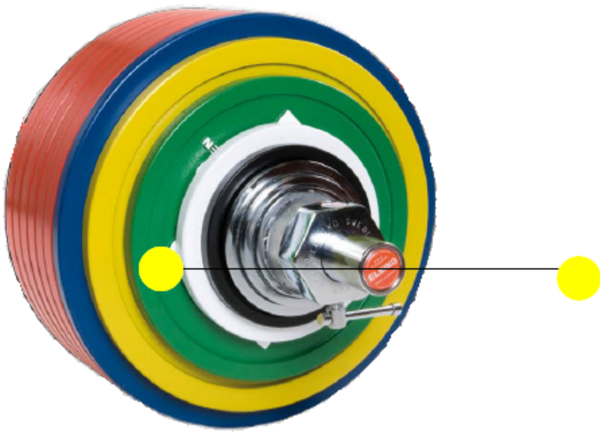

Figure 2 - ProReflex marker from the end. Picture obtained from Eleiko AS product catalogue.

The ProReflex markers were placed on the subjects on the: ankle (malleolus lateralis), knee (lateral epicondyle of the femur), pelvis (middle of Iliac crest), wrist (caput ulnae), vertebrae lumbales (L3) and vertebrae cervicales (C7). EMG-electrodes were placed on the subjects m. vastus medialis, m. gastrocnemius (medialis), m. biceps femoris, m. gluteus (maximus), m. longissimus and m. trapezius (middle).

Standardized methods

The following standardized methods were used. All subjects were prepared in same procedure, with shaving the skin and disinfecting the areas where the EMG-electrodes and ProReflex markers were placed. The EMG-electrodes and ProReflex markers were attached with double-sided tape. All subjects used the same warm up program before starting the data collection (see attachment 1). A standardized grip width was given since different grip width will cause differences in how the barbell behaves. This is not the case with foot stance therefore a standardized foot stance were not given, but was limited by the Kistler force plate (60 cm width).

To ensure standard barbell properties two new barbells were purchased. The level difference between the force plate and the weightlifting platform was measured to be at1mm, which is a negligible level difference since it is the same level difference for all of the subjects. A standardization of minimum 2 min and maximum 5 min rest between the lifts were established.

Deadlift & procedure

To measure the effect the two barbells could have on physical load, such as EMG-activity, force production and technique, we chose to measure this in one exercise from PL, deadlift. Deadlift involves lifting the barbell from the ground in the "die-position", up to the hips so that your knees are fully stretched out and your back is in upright position. The most common technique is to stand shoulder width with your feet, placing your feet under the barbell and slightly forward so you can see your toes on the "other side" of the barbell. Bend down and grab the bar with either supinated grip, pronated grip or combined grip, and often shoulder-wide grip. Hold your back naturally straight throughout the movement (Refsnes, 2010).

Picture 1 – Subject standing still on the force plate, ProReflex and EMG-electrodes placed on and are ready to performing the deadlift.

Deadlift was chosen because of it is movement path that are familiar to the first pull in C&J and is a known support exercise for OWL, CF and PT. A full range movement like C&J was not selected due to the narrow range of lifters in Sør-Trøndelag who can perform this exercise in a correct manner at the required weight. All subjects were explained the same procedure before starting the data collection. The task for the subjects was to do one repetition deadlift every 2-5 minutes, and total 12 times. Eight subjects were starting with the OWL-barbell and eight subjects were starting with the PL-barbell. Since we wanted to avoid a possible habituation phase during the study, the subjects were told to lift with their own technique they were used to at training and competition.

A counter balanced way of starting and finishing with OWL-barbell or PL-barbell were used (see table 2), to find or eliminate the time and fatigue effect during these successive lifts. There was also a practical reason behind this choice, as loading and reloading the barbell every other attempt is not feasible in the long run. The space it requires to load both barbells simultaneously was also not possible.

Table 2 shows the arrangement of groups, with the number of subjects, the order of the barbell used and the number of lifts with which barbell.

Group	**Subjects**	**Barbell (lifts)**	**Barbell (lifts)**	**Barbell (lifts)**	**Total lifts**
		Part 1	Part 2	Part 3	
Group A	8	OWL (4)	PL (5)	OWL (3)	12
Group B	8	PL (3)	OWL (5)	PL (4)	12

Subject equipment & restrictions

Normal, OWL, PL or CF-shoes were allowed as long as it didn't cover up the ankle joint, lifting barefoot was also allowed. Use of lifting straps, magnesium powder or liquid climbing chalk was allowed. Powerlifting suit, belt and any kinds of joints warmer were not allowed due to the support for joints and muscles during the lift, as well as being an obstruction for the ProReflex markers. The subjects lifted in bare-chested, shorts or tights (which did not go over the knee) and socks (that didn't cover up the ankle joint).

The data collection started 1.november 2012 and ended 13.desember 2012. Two subjects and eight lifts were drawn from the analysis due to technical error during data collection.

ANALYSIS

The first part of the analysis work consisted of identifying all ProReflex markers in the computer program QTM. Before the analysis could start in Matlab, each file needed to be manual edited in order to calibrate baseline to zero kg (0 kg) and the subject's bodyweight (BW). Since each file was equal according to force trace, this made it easy for Matlab to recognize the defined periods that were set for the analysis. Table 3 explains the highlights periods during this study, acronyms for these periods are made and will be become regulars in the subsequent text.

Table 3 includes the defined time periods and explanation of these.

Definition of analysis periods	Explanation
Baseline (A)	Calibration of 0 kg, mean of manually identified time period by visual inspection
Bodyweight (B)	Calibration of bodyweight, mean of manually identified time period by visual inspection.
Start (C)	Subjects start to lift.
InitLift (IL) (C-D)	Barbell starts to bend until the barbell has left the ground. Based on velocity of barbell above 2sd, measured in baseline. Measured in meters.
Initiation Time (IT) (C-D)	Barbell starts to bend until the barbell has left the ground. Based on velocity of barbell above 2sd, measured in baseline. Measured in seconds.
RFD (C-D)	Mean of all lifts, max(df/dt) calculated using a differential filter.
Top of the lift (F1)	Mean of two points, first time to be zero force after lift off. Subjects stand upright with the barbell.
MoveTime (MT)	From beginning to end: Point C-F2
MaxMoment & EMG Earlystart	Mean of time period from C-D.
Moment- & EMG all move	Mean of time period from C-F1.
Moment- & EMG hold steady	Mean of time period from F2-G.
MaxFz	Maximum force created during the lift.
BarOS & BarSS (abstract value)	Bending was estimated by using the second order constant of a second order polynomial fit of vertical vs. horizontal positions of the 5 recorded points of the barbell at maximum loading. Stiffness is weight/c.
BarW	Total load – bodyweight.

Calibration

Calibraton of baseline (0 kg) was done before the subjects entered the force plate. Bodyweight calibrations of the subject's were done either before or after the lift, choosing the one with the best steady constant signal. Most of the defined time periods are mean of signal between two points manually determined. Figure 3 visualize how it is done, as marker one being at 0,5 seconds and marker two being at 1,0 seconds in the baseline (A) period. Same procedure was done at finding the subject's bodyweight (B), where a good signal quality enters at approximately 4 seconds.

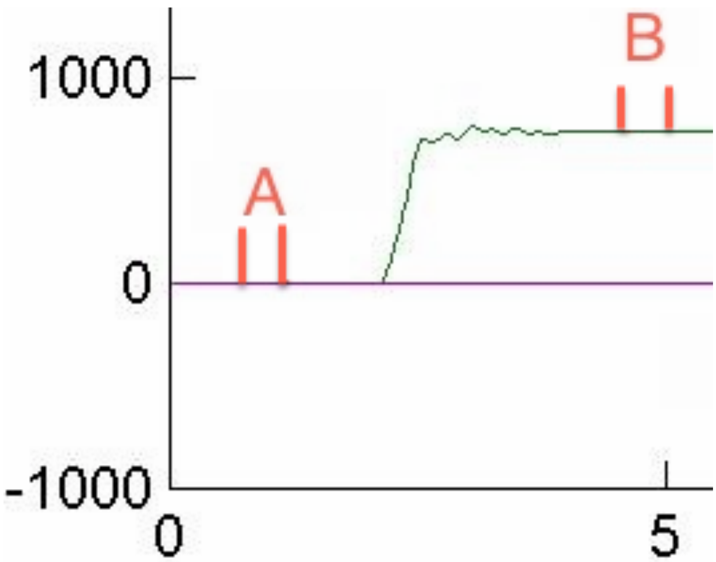

Figure 3 –Baseline and bodyweight. Y-axis: Kg. X-axis: Seconds.

To ensure that the measurements made by the system were correct, a quality check was done. Two checks were done, the first one was to compare the stiffness in the barbells (BarOS & BarSS). The second check was to find the weight the subjects lifted (BarW) and compare to the actually weight. Request about the properties to our provider of the barbells were done, but they couldn't release that information due to security standard made by Eleiko AS.

Bending was fitted using a second order polynomial; $Y= a+bx+cx^2$ where weight/C is the stiffness measure.

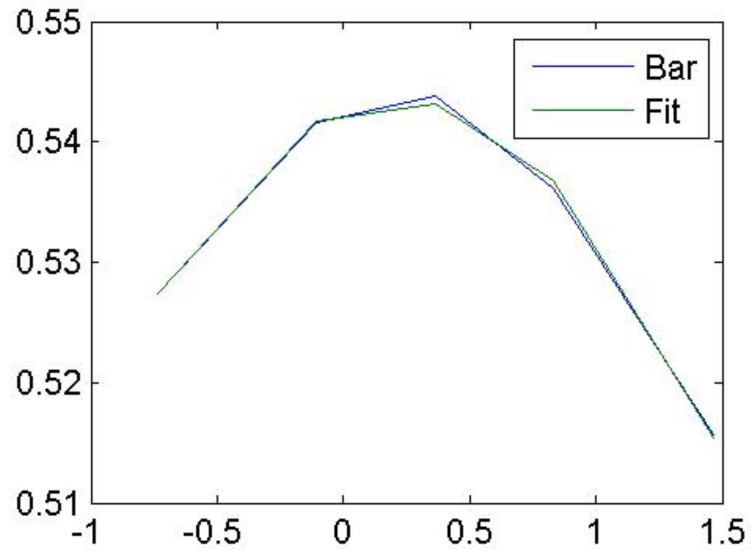

Figure 4 - Barbell bending in 2D and the fitted polynomial. Y-axis: Height. X-axis: Barbell length.

Forces & time

Figure 5 shows what happens during a single lift. Point C is where the lifter starts to lift the barbell from the ground, this analysis is based on when the velocity is one percentage of maximum velocity during the lift. This is done to guard us against starting the measurements on baseline noise. At point D, according to dynamics the barbells has barbell have left the ground. D is the point when the force exceeds bodyweight and barbell load together. It is also based on ProReflex markers on the outside point of the barbell. Upward movement of the outer point indicates lift of. These 2 events (forces; BW and barbell weight, and outer marker lift of) always occurred very close together in time. The time between point C and D is IT, this is where we measured in seconds how long time it took from when the middle of the barbell started to move until the barbell has left the ground. C-D is also where the RFD is calculated. Point F1is where the subjects stand still at the top of the lift, this point is measured in basis of when the velocity goes trough zero for the first time after lift of. Point F2 is the second time the velocity goes trough zero (coming from negative). G is the end of the hold period, velocity drops below zero. The hold period is defined from F2-G, where the requirements for the barbell were to be at ease for 250ms to be approved for the analysis.

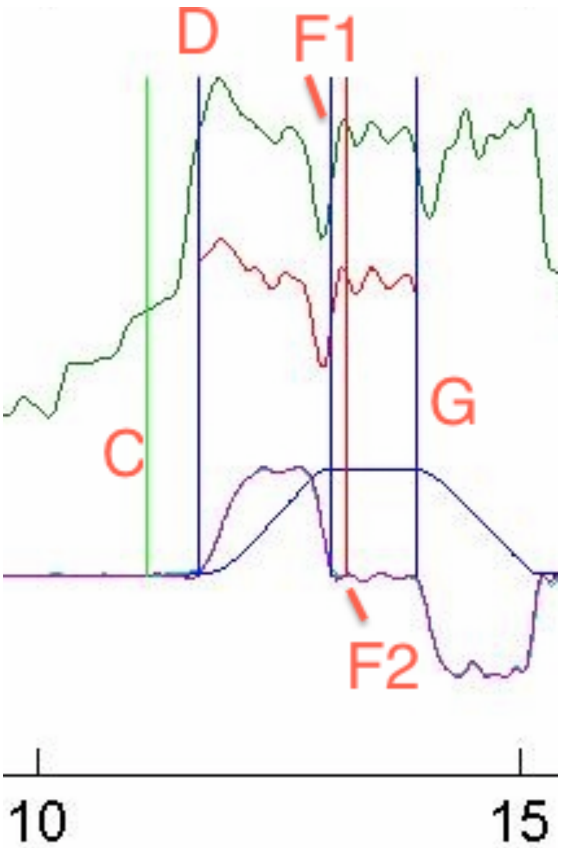

Figure 5 –Force trace with subsequent time periods. Y-axis: Bodyweight + barbell weight. X-axis: Seconds.

EMG & moment

Our EMG-activity and moment measurements are measured in three parts of the lift. Both EMG and moment are measured at same period of time during the lifts. EMG was integrated as root mean square (RMS). First measurement part, maxmoment & EMG earlystart, where the time period is from C-D. Second part is Moment allmove & EMG allmove, where the time period is from C-F1. Third part is moment holdsteady & EMG holdsteady at point F2-G.

Technique & repetition

The analysis of the barbell trajectory path was done by finding the centrum of the two ProReflex markers at the end of one side of the barbell. The joint positions was as well measured as a part of the technique, here the changes is position of the ProReflex markers at the joints were compared against each other. The analysis also took a look at repetition series effect. Here the analysis run all lifts in succession from repetition one to repetition 12, regardless of which barbell used. Repetition series effect would give a more evident picture of what is causing the results that have been collected.

Statistics

Paired t-test was used comparison average of all lifts with the OWL and PL barbells.

RESULTS

Most of the results are an outcome of the average of the time periods, shown in table 3. In table 4 and table 5 the results will be presented and referred to during this chapter.

Table 4. Results of the barbell properties and psychical load (mean ± SD).

	OWL			PL			P
Barbell properties							
Barbell stiffness (c i polynomila fit)	71574	±	4611	85502	±	9818	0,00008*
Initial Lift (IL) (meter)	0,02	±	0,004	0,016	±	0,003	0,00043*
Barbell weight (kg)	168,24	±	24,69	168,22	±	24,77	0,918
Pyshical load							
IT (seconds)	0,64	±	0,33	0,66	±	0,45	0,776
Movetime (seconds)	2,42	±	0,64	2,47	±	0,77	0,546
RFD (N/s)	4857	±	1632	4881	±	1742	0,810
MaxFz (N)	2855	±	410	2842	±	421	0,302

* Significant difference ($P < 0.05$) between OWL-barbell and PL-barbell.

Table 5. Results of the moment on joints and muscle activity (mean ± SD).

	OWL			PL			P
Joints (N/m)							
Maxmoment							
Wrist	236	±	105	253	±	130	0,404
C7	911	±	219	904	±	230	0,680
L3	849	±	166	855	±	177	0,699
Pelvis	637	±	181	639	±	168	0,882
Knee	384	±	141	384	±	130	0,995
Ankle	481	±	109	480	±	108	0,961
Allmove							
Wrist	-28	±	113	-24	±	121	0,853
C7	-90	±	126	-90	±	135	0,970
L3	565	±	152	560	±	149	0,708
Pelvis	440	±	139	436	±	135	0,751
Knee	82	±	131	72	±	130	0,505
Ankle	308	±	97	302	±	97	0,709
Holdsteady							
Wrist	132	±	112	138	±	139	0,751
C7	782	±	205	768	±	214	0,356
L3	706	±	148	701	±	159	0,735
Pelvis	392	±	136	390	±	141	0,914
Knee	250	±	123	248	±	125	0,903
Ankle	406	±	104	399	±	106	0,632
EMG (mv)							
Early start							
Trapezius, middle	202	±	114	215	±	127	0,149
Longissimuss	243	±	129	255	±	125	0,059
Gluteus maximus	81	±	55	86	±	68	0,373
Biceps femoris	89	±	102	103	±	131	0,176
Vastus medialis	246	±	135	250	±	143	0,663
Gastrocnemius	70	±	50	73	±	54	0,507
Allmove							
Trapezius, middle	270	±	135	275	±	143	0,299
Longissimuss	272	±	147	279	±	146	0,227
Gluteus maximus	146	±	91	148	±	94	0,752
Biceps femoris	189	±	103	194	±	111	0,371
Vastus medialis	210	±	98	202	±	97	0,291
Gastrocnemius	123	±	66	125	±	65	0,623
Holdesteady							
Trapezius, middle	210	±	103	214	±	108	0,445
Longissimuss	85	±	48	90	±	60	0,450
Gluteus maximus	76	±	56	70	±	50	0,097
Biceps femoris	86	±	62	87	±	60	0,630
Vastus medialis	67	±	37	57	±	36	0,017*
Gastrocnemius	88	±	57	92	±	53	0,620

* Significant difference ($P < 0.05$) between OWL-barbell and PL-barbell.

Barbell properties & physical load

Different barbell properties were found to be significant, when both stiffness and IL measurements were found significant. Other measurements such as MaxFz, RFD, MT and IT were not significant.

EMG & moment

Of the 16 subjects and 18 EMG measurement per subject, there was one significantly EMG-activity measurements. In EMG holdsteady m. quadriceps vastus medialis, one measurement had a trend, in EMG earlystart m. erector spinae longissumus. Three other measurements had low numbers (m. trapezius middle at EMG earlystart, m. hamstring biceps femoris at EMG earlystart and m. gluteus maximus at EMG holdsteady). Six measurements during max moment where non significant, two were very high at the knee and ankle. In moment allmove, all six measurements where also non significant, one very high (C7). At moment holdsteady there were two high numbers, pelvis and knee, also here non significant results.

Technical aspects

There are different barbell trajectories at each lift, these difference are found to be non significant, see figure 6.

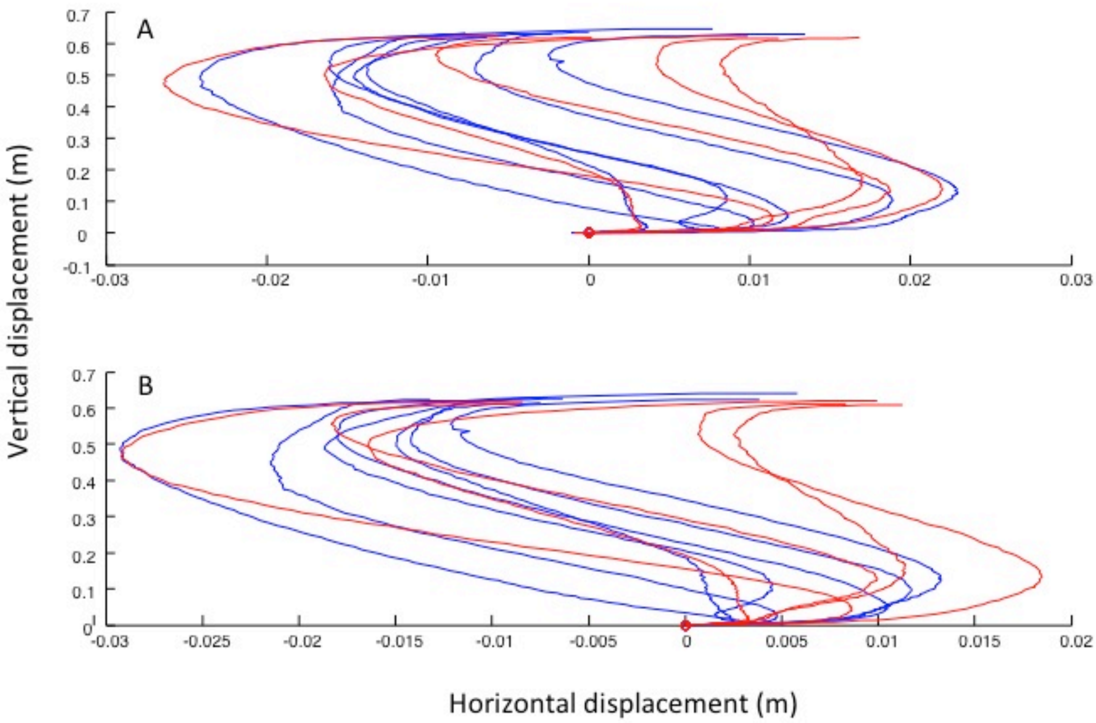

Figure 6 – Barbell trajectories of OWL-barbell (blue) and PL-barbell (red). A: synchronized from initial move (point C). B: synchronized from dynamic start (at the end of IL, point D).

Figure 7 shows the positions of the pelvis and knee at one subject during all twelve deadlifts. The difference between the joint positions that occurred is found to be not significant.

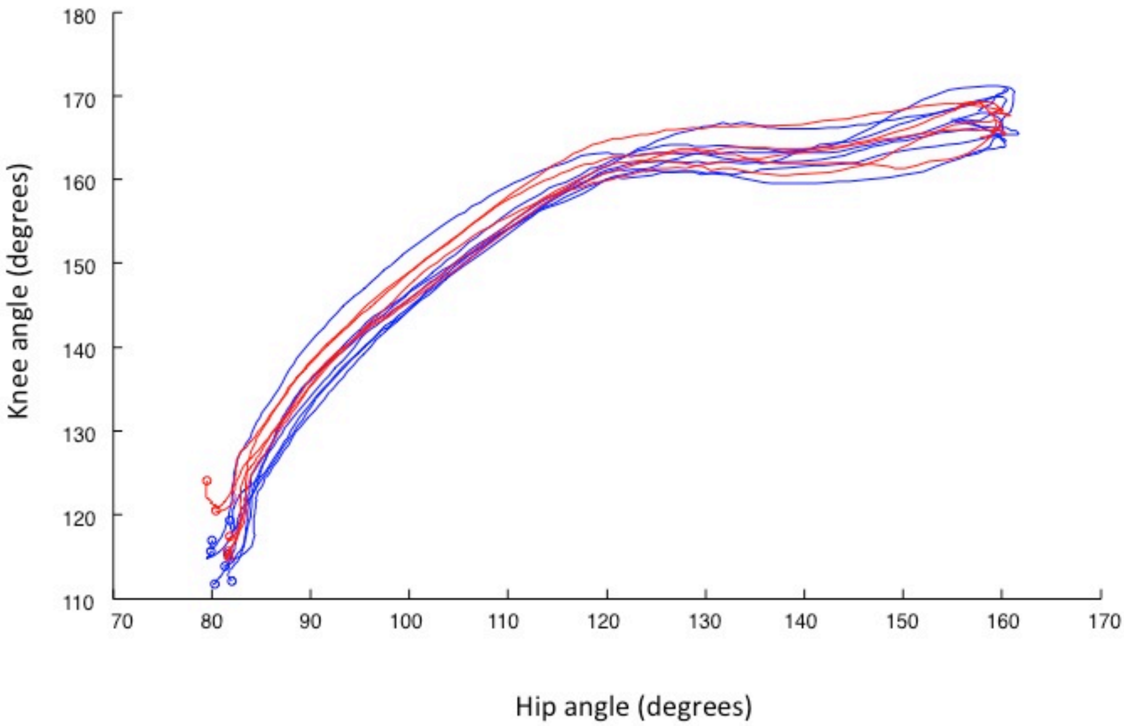

Figure 7- Joints positions of the pelvis and knee with OWL-barbell (blue) and PL-barbell (red).

Repetition series effect

As Figure 8 illustrates, the sequence of lifts from repetition 1 to repetition 12, shows that the barbell swapping have no significantly effect on these measurements shown in the figure. It also shows that the time effect were not present.

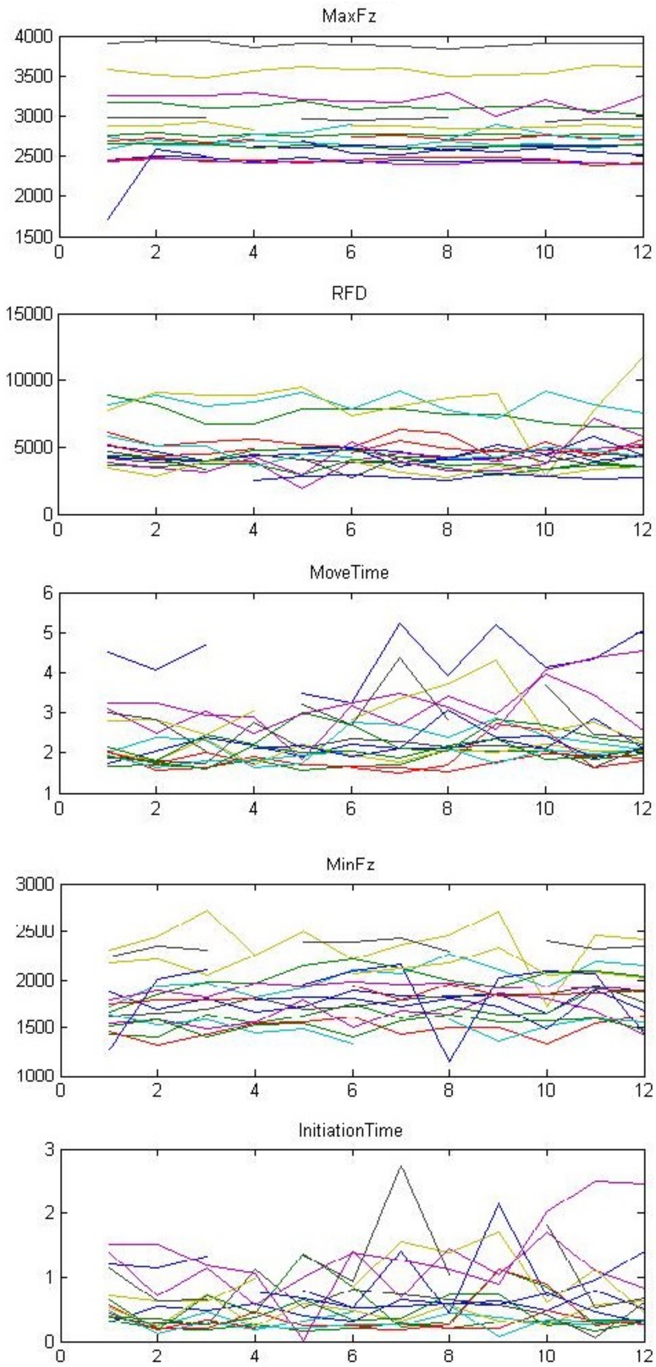

Figure 8 - Shows the repetition series effect in MaxFx, RFD, MT, MiniFz and IT.

Main results

According to our study there was no significance difference between the OWL-barbell and the PL-barbell in psychical load on EMG-activity, technique changes, force production or joint moment in the lift and hold periods. Neither was there a significant difference between the lifts from 1 to 12, which indicated that there was no time effect at the subjects. But as expected there are clearly significantly differences in the qualities between the barbells, which were measured both in our barbell stiffness test and initial lift amplitude period that both were significant.

DISCUSSION

Barbell properties

Goal of this study was to investigate the possible differences in physical load in deadlift due to the barbell differences. It was hypothesized that there would be differences in EMG-activity, force production, moment at joints and technique, due to the barbells different qualities. The hypothesis did not match up with the results, very few significantly differences were identified. This lack of differences is unlikely due to inaccuracy of the measurements as these did capture differences in barbell properties (barbell stiffness and initial lift). The results from the barbell properties were significant differences in the stiffness between the barbells. This confirms our hypothesis about two barbells with different qualities. The difference in barbell properties were also confirmed again when that initial lift was found to be significant with its 4mm of difference.

Accuracy of the measurement system was also confirmed by measuring the subject's total load on the barbell, which reach a high number (see table 4). This result should be at one but this can be explained by the small differences between each lift. The barbell will bounce more or less at each lift and the system correctly measurer these small differences. This means that the system measure 176,1 kg at one attempt, 176,2 kg and 176,0 kg at the next attempts due to fluctuations in the barbell. Our measurement instruments (ProReflex markers and clamps) are on the barbell without being weighed since they weigh so little. All together our measurements are measuring what we want in an accuracy method.

Study design

Group A did 1 more lift with the opposite barbell to Group B in part 1 (se table 2), and one less lift at part 3. With this method possible differences occurring at repetition 3 and 4 would be will be given a causal, barbell swap, instead of the possible fact that when executing 3 repetitions, the 4 repetition will give this response on the physical load. This method will give a stronger indication of why the possible differences occur.

Comparison with literature

One of the hypotheses before the study was that the EMG-activity should be different when the total weight of the loaded barbell burdens the lifter at different times through the lift. This seemed not to be the case in this study, when the measurements of six muscles at three time periods during the lifts were significantly different in only two cases. This is more likely to be explained by some accidental changes (chance) during the lifts rather then a systematic difference between barbells. Because of some data error and several pore signal quality during EMG-measurements (leading to excluding of some EMG results), the author are aware of that the results about EMG-activity is not as well documented as the dynamics. It is therefore interesting to measure the EMG-activity during different exercises with these two barbells with more participants.

Findings in this study are different from Escamilla et al., (2002) study about electromyography analysis of sumo and conventional style deadlifts where several small, but significant differences were found. This can indicate that it has more to say which variation in the execution of the exercise (feet and grip position) you chose instead if which barbell. This assumption is also be supported by Swinton et al., (2000) who compared a straight barbell against a hexagonal barbell (subjects stands inside a frame), which gives the subject new grip width, grip angel and feet stance. They found several significantly results such as peak velocity, peak force and peak power and a significantly higher 1RM with the hexagonal barbell. These two studies have in common the variation of feet and grip position in contrast to our study that standardized the grip width and feet width was limited by the force plate. Several studies have also been done at stance width in squat, such as Paoli et al., (2009) who found enhanced EMG-activity of the gluteus maximus during large stance, but also found non-significant differences at the seven other muscles comparing different stance widths. Boyden, et al., (2002) compared the angle of the foot position in squat (-10°, 0°, 10° & 20°) at 65 % and 75 % of 1 RM. EMG-activity were measured at vastus medialis, vastus lateralis and rectus femoris, several small differences were found, the main results were higher EMG-activity at 20° foot angel at both loads but non-significant. All of these studies indicate that there are differences when changing the barbell design drastically (hexagonal barbell) or making different stance and grip position.

Study limitations

The psychological factors in this study are the barbell swapping during the lifts, the unavoidable fact that they are going to do 12 lifts in total, adjusting to the standardized grip, the limited stance width and avoiding breaking ProReflex clamps at the middle of the barbell. There is a chance that the subjects were "expecting" different technique or easier/heavier lifts after the barbell swap. Therefore they could consciously be more aware of, or changing their technique on the basis of the barbell switch. Some subjects also indicated that the 12 lifts expectation was stress full, others had an pacing method at the first lifts. The placement-standardization of measuring instruments on the barbell, subjects and standardization of grip and foot width (Kistler force plate allowed 60 cm foot-width) could have affected the subjects normal technique more for some subjects than others. This could have created a habituation phase during the first lifts for some subjects, instead of lifting with their normal technique. The possibility that the subjects never have lifted with the opposite barbell could mean another habituation phase going on at the first lifts with the opposite barbell. These factors are checked in the repetition series analysis, which were found not to be present or too small differences to influence the results significantly.

It is rather surprising that differences in the barbell trajectory did not reach significant levels, when the measurement shows that the barbell bends differently through the lifts, which means that the load of the barbell burdens the lifter at different time periods during the lift. It may be that the lifters are holding the joint positions for a longer or shorter time period according to which barbell used, to create the same barbell trajectory. It is also likely that the differences we found in the barbell (IL) were so small that the body compensated, may have been spread over the hole body segments so that they become unnoticeable.

Practical implications

According to the results we can imply that it requires equal force production with both barbells to lift 150 kg up to 220 kg. EMG-activity, joint moment and technique are not affected significant. This indicates that the barbell choice will not affect the training effect. Nor can we say that either barbell can reduce stress on certain body parts then the other. How this will work in a real life training period is not something this study can consider. The small differences found could play a more important role over a longer period of time.

Further research

It must also be noted that hypotheses may apply other exercises that require more technique skills. It could be a good ide to test this hypothesis also at more extreme weights (national level) and at maximal weights for the subjects instead of submaximal weights. Especially when the PL-barbell is made to handle extremely heavy weights and most of the technique in OWL is depending on the bounce from the barbell, especially the jerk. Therefore bigger differences between the barbells are likely to be found.

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ATTATCHEMNT OVERVIEW

Attachment 1: Warm up program

Attachment 1

Attachment 1 shows the warm up regime. Those who lifted 150 kg in the study started after completing 3 repetitions on 130 kg. Those who wanted more then 150 kg, did 2 repetition on 150. They then did 1 repetition up to that weight they wanted.

<table>
<tr><th colspan="3"><u>Protocol</u></th></tr>
<tr><td>Frontsquat, Deadlift, Stiff deadlift</td><td rowspan="2">5 rep x exercise</td><td rowspan="2">3 set</td></tr>
<tr><td>20 kg</td></tr>
<tr><td>Only deadlift from here</td><td rowspan="2">5 repp</td><td rowspan="2">1 set</td></tr>
<tr><td>70 kg</td></tr>
<tr><td>100</td><td>5 repp</td><td>1 set</td></tr>
<tr><td>130</td><td>3 rep</td><td>1 set</td></tr>
<tr><td rowspan="2">150</td><td>1 rep</td><td>12 set</td></tr>
<tr><td>2 rep</td><td>1 set</td></tr>
<tr><td>170</td><td>1 rep</td><td>1 set / 12 set</td></tr>
<tr><td>190</td><td>1 rep</td><td>1 set / 12 set</td></tr>
<tr><td>200</td><td>1 rep</td><td>1 set / 12 set</td></tr>
</table>