A comparison of isolated lumbar extension strength in competitive and non-competitive powerlifters, and recreationally trained males.

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ABSTRACT

Low back strength has been shown to significantly impact performance in a plethora of sports. Aside from its effect on sport performance, low back strength is strongly associated with low back pain. A sport that heavily involves the lower back musculature is powerlifting. The present study looked to compare isolated lumbar extension (ILEX) strength in competitive and non-competitive powerlifters and recreationally trained males. Thirteen competitive powerlifters (CPL group; 31.9 ± 7.6 years; 173.4 ± 5.5 cm; 91.75 ± 18.7 kg), 10 non-competitive powerlifters (NCPL group; 24 ± 3.5 years; 179 ± 4.8 cm; 92.39 ± 15.73 kg, and 36 recreationally trained males (RECT group; 24.9 ± 6.5 years; 178.5 ± 5.2 cm; 81.6 ± 10.0kg) were tested for isolated lumbar extension strength (ILEX). ILEX strength was measured at every 12° throughout participant's full range of motion and expressed as the following: 'strength index' calculated as the area under a torque curve from multiple angle testing (SI), average torque produced across each joint angle (AVG) and maximum torque produced at a single angle (MAX). Deadlift and squat strength was measured using 1 repetition maximum (1RM) for the competitive and non-competitive powerlifters. The following powerlifting characteristics were recorded for the competitive and non-competitive powerlifters: primary deadlift stance, primary squat bar position, use of belt, use of performance enhancing drugs (PEDs) and use of exercises to target the lower back musculature. Significant between group effects were found for participant characteristics (age, stature, body mass, and range of motion). However, analysis of covariance with participant characteristics as covariates found no significant between group effects for SI (p=0.824), AVG (p=0.757), or MAX (p=0.572). In conclusion this study suggests that powerlifting training likely has little impact upon conditioning of the lumbar extensors.

Keywords: powerlifting; lumbar extension strength; resistance training

INTRODUCTION

It is commonplace for strength and conditioning coaches and exercise professionals to use traditional powerlifting exercises such as the squat and deadlift within their training, and often with a view to increasing lumbar extension strength (18). Indeed, the squat exercise is shown to place great stress on the lumbar musculature (3) and shows considerable activation of the lumbar muscles when measured using electromyography (EMG; 29,13). Since the squat exercise shows a strong relationship to athletic performance such as sprint speed (r=0.71-0.94) and vertical jump (r=0.78; 26) it is not a surprise that this exercise is fundamental to most strength and conditioning programs.

However, Fisher, et al. (9) reported that following a 10-week intervention trained males performing the Romanian deadlift (RDL) exercise showed no increase in isolated lumbar extension (ILEX) strength despite significant increases to their RDL 1-repetition maximum (RM). In contrast, a group training using ILEX showed significant increases in ILEX strength as well as in RDL 1RM. Low back strength is evidenced to impact performance across a variety of sports (including golf, weightlifting, powerlifting, soccer, ballet, etc.; 19). Furthermore, since deconditioning of the lumbar extensor musculature appears closely related to low-back pain (25), it might be important for competitive athletes and coaches who are looking to maximize performance and minimize risk of injury to consider lumbar extension strength. As such it is important to elucidate the relationship between exercises such as the squat and deadlift, and ILEX-strength.

Athletes competing in the sport of powerlifting represent a unique population group whose aim is to develop maximal strength in the back squat, deadlift, and bench press exercises. Powerlifters often use derivatives of the 3 powerlifts to address movement specific weaknesses as well as exercises to specifically target the lower back musculature (eg: good mornings, trunk extensions etc). Most powerlifters use a stiff weightlifting belt in order to perform a breathing technique called the valsava maneuver which allows them to increase intra-abdominal pressure by pushing against the belt with their abdominal muscles. Using a stiff belt for squats and deadlifts has been shown to increase strength as well as increasing activation in different muscle groups (lumbar erectors, quadriceps etc) (16). It is important to note that powerlifters perform the squat with two different techniques, “high bar” and “low bar”. The two different squat techniques are concerned with the placement of the bar on the back. The “high bar” squat requires the lifter to place the bar centered across the shoulders whereas the “low bar” squat requires the lifter to place the bar further down on the back across the spine of the scapula (28). Most competitive powerlifters utilize the “low bar” squat as their main primary squat technique due to its influence on squat kinematics and kinetics, which allows them to be more efficient in lifting a load (10). Studies investigating the “low bar” squat have noted that the forward tilt of the torso, due to the lower placement of the bar on the back, increases the forces in the lumbar muscles and ligaments (10). Powerlifters perform the deadlift with two different stances, conventional and sumo. The main difference between conventional and sumo deadlifts are that the feet are positioned further apart and pointed out in the sumo stance, while the arms are placed between the knees for the sumo stance and outside the knees for the conventional stance. Further, EMG data also shows that many of the typical deadlift variations performed by powerlifters (e.g. conventional, sumo, or Romanian) also all involve considerable, and similar, EMG amplitudes in the lumbar musculature (8,13).

However, there are several limitations to using and interpreting EMG data as discussed by De Luca (6) who explained that, amongst other things, EMG signals often include readings from synergist muscles. Further, EMG data does not enable inference that an adaptive response is likely to occur (12). As such it might be more prudent to consider population groups who have excelled in these exercises. Both squat and deadlift exercises heavily recruit the posterior chain and are often trained with high load, large volume and, in some cases, with very high frequency (26). As such, if the squat and deadlift exercises produce a meaningful training effect in ILEX strength it would be most evident in a cross sectional comparison including this population group. Therefore, the aim of this study was to investigate ILEX strength in competitive and non-competitive powerlifters, in addition to a recreationally resistance trained population.

METHODS

Experimental approach to the problem

A cross sectional, between group comparative design was utilized. In order to compare ILEX strength in competitive and non-competitive powerlifters, in addition to recreationally trained males, all participants underwent ILEX strength testing. All non-competitive powerlifters underwent 1RM testing for the squat and the deadlift as did competitive powerlifters unless they had competed at an official powerlifting competition up to 3 weeks prior to the week of ILEX strength testing where this was used as their 1RM instead. Participants took part in two ILEX testing sessions; a familiarization session and a strength testing session. A plethora of training variables (primary deadlift stance, primary bar placement for the squat, use of specific exercises to target the lower back musculature etc) were recorded for the competitive and non-competitive powerlifters.

Participants

Approval by the relevant ethics committee at the researcher's institution was initially obtained (Health, Exercise, and Sport Science Ethics Committee Id No. 769). Following this a total of 52 males with at least 2 years resistance training experience, either identifying as being 'powerlifting style training' or merely 'recreational resistance training', were recruited. Those participants performing 'powerlifting style training' also reported whether they competed in powerlifting meets and if so at what level. The differentiation between competitive and non-competitive powerlifters was made as competitive powerlifters tend to deviate less from the powerlifts (the squat, the bench press and the deadlift) and often train them and their derivatives throughout the whole duration of their macrocycle. Non-competitive powerlifters may often train the powerlifts with less volume or for less amount of time throughout a macrocycle as they are not required to optimize their performance for competition.

Powerlifting participants

Ten non-competitive powerlifters (NCPL group) and 13 competitive powerlifters (CPL group) were recruited through word of mouth by one of the study's researchers who is a competitive powerlifter. The CPL groups competitive experience varied; most participants had competed at a national level (n=6), some at the divisional level (n=4) and a few at the international level (n=3; i.e. IPF/GPA Greek/British nationals & GPA/IPF worlds).

Recreationally trained participants

Thirty-six recreationally trained males (RECT group) were recruited through an advertisement within a University environment that requested participants who were not suffering from any low back pain. Prior to participation, all participants received a participant information sheet describing the procedures to be completed and were asked to provide signed informed consent. These participants were part of a previous investigation (9).

Procedures

Testing

1. ILEX strength testing

Participants were seated in the ILEX device (Lumbar Extension Machine, MedX Corporation, Ocala, FL). The ILEX device utilizes restraints in order to limit unwanted pelvic involvement in an upright position with their thighs at an angle of 15° to the seat in the testing (see figure 1) in addition to a counterweight to neutralize the effects of gravitational forces on the head, torso, and upper extremities. The set-up and testing using the ILEX device has been described in detail previously (5). In brief, range of motion (ROM) was established by placing the participants in full extension and full flexion. Participants then completed a slow, controlled dynamic warm-up lasting approximately 1 minute, then a practice isometric test at 50% of perceived maximal effort at 3 angles (full flexion, mid-ROM, and full extension), before finally completing a maximal voluntary isometric effort at 5-7 angles throughout their full ROM (0, 12, 24, 36, 48, 60, and 72 degrees). Participants were asked to build up maximal effort over 2-3 seconds and to maintain that effort for a further 2-3 seconds. Between each effort a 10 second rest period was provided where participants were rocked gently back and forth through their ROM. ILEX torque measurements show very high test and retest reliability for both asymptomatic participants and patients with low back pain (11,20).

2. Powerlifting strength testing

The competitive powerlifters that had competed in an official powerlifting competition up to 3 weeks away from the ILEX strength testing session were excluded from the squat and deadlift 1RM testing. Their latest competitions lifts were used as their 1RM results. All other powerlifters, competitive and non-competitive, were required to take part in 2 different 1RM testing sessions. The first testing session tested the participants’ 1RM for the squat and the second session tested the participants’ 1RM for the deadlift. Initially the participants prepared for the 1RM attempt by following a warm up protocol. They started by performing 5-10 repetitions with an empty bar for 2 sets, 5 repetitions at 30% and 50% of their most recent 1RM, followed by 3 repetitions at 70% and 80%. Each participant was then given 3 attempts to perform a maximal lift with approximately 3-5 minutes of rest in between to allow for adequate recovery. The 2 sessions were 48 hours apart to allow for proper fatigue management.

Powerlifting Characteristics

Competitive and non-competitive powerlifters were required to give information on the following powerlifting characteristics during their ILEX strength testing session: primary squat bar position, primary deadlift stance, use of belt during working sets for the squat and deadlift, use of performance enhancing drugs (PEDs) in the last 2 years, and whether they used specific exercises to target the lower back musculature (LBex) in the last 3 years.

Statistical Analysis

Analysis was conducted using JASP (version 0.8.2, Amsterdam, Netherlands). Descriptive statistics (means and SDs) were derived for demographic data and strength variables. Strength was examined as a strength index (SI), calculated as the area under the strength curve using the trapezoidal method thus incorporating strength at all tested angles, in addition to the average of all angles tested (AVG), and the maximum torque produced at a single angle (MAX). Dependent strength variables met assumptions of normality of distributions when examined using a Shapiro-Wilk test. A one-way analysis of variance (ANOVA) test was used to examine between groups effects for participant characteristics including age, stature, body mass and ROM. An independent t-test was used to examine between groups differences for the NCPL and CPL group for powerlifting strength (squat & deadlift 1RM). Powerlifting characteristics (primary squat bar position, primary deadlift stance, belt use, PEDs use and use of specific exercises to target the lower back musculature) were examined using a chi-squared test and presented in a contingency table**.** A one-way analysis of co-variance (ANCOVA) test was used to examine between groups effects for ILEX strength (SI, AVG, and MAX) with the participants' height, weight, age and ROM as covariates. Assumptions of linear relationships and homogeneity of regression slopes was confirmed visually. Age was included as a covariate as it known to significantly impacts upon muscular strength; bodyweight was also included as a covariate as it can have a significant effect upon strength and muscle mass; height was included as a covariate as due to differences in moment arms resulting from it may impact the torque. ROM was included as a covariate as it has a significant effect on the SI and AVG values. A one-way analysis of co-variance (ANCOVA) test was used to examine between groups effects for the NCPL and CPL group for ILEX strength (SI, AVG, MAX) with the participants' squat 1RM, deadlift 1RM, PED use, primary squat bar position, primary deadlift stance, belt use and use of exercises to target the lower back musculature as covariates. Post hoc Tukey's HSD was used to compare between groups where any significant between groups effects were observed. Significance was set at an α of 0.05.

RESULTS

1. Participant Characteristics:

TABLE 1 HERE

Participant characteristics are shown in Table 1. A one-way ANOVA test revealed a significant between groups effect for age ($F_{(2,56)}$ = 6.475, *p*= 0.003). Post hoc Tukey's HSD revealed a significant difference for age between NCPL and CPL (*p*= 0.015), and between RECT and CPL (*p*= 0.003). There was no significant difference for age between NCPL and RECT (*p*= 0.950).

A one-way ANOVA test revealed a significant between groups effect for stature ($F_{(2,56)}$ = 5.316, *p*= 0.008). Post hoc Tukey's HSD revealed a significant difference for stature between NCPL and CPL (*p*= 0.027), and between RECT and CPL (*p*= 0.009). There was no significant difference for stature between NCPL and RECT (*p*= 0.934).

A one-way ANOVA test revealed a significant between groups effect for body mass ($F_{(2,56)}$ = 4.274, *p*= 0.003). Post hoc Tukey's HSD revealed a significant difference for body mass between NCPL and RECT (*p*= 0.069), and between CPL and RECT (*p*= 0.057). There was no significant difference for body mass between CPL and NCPL (*p*=0.993).

A one-way ANOVA test revealed a significant between groups effect for ROM ($F_{(2,56)}$ = 15.96, *p*= 0.001). Post hoc Tukey's HSD revealed a significant difference for ROM between NCPL and RECT (*p*=0.005), and between CPL and RECT (*p*=0.001). There was no significant difference for ROM between CPL and NCPL (*p*=0.420).

2. Powerlifting Characteristics

TABLE 2 HERE

Powerlifting characteristics are shown in Table 2. A chi-square test revealed no significant difference for deadlift stance between NCPL (70% conventional, 30% sumo) and CPL (69.3% conventional, 30.7% sumo), (X^2 (1, n=23) = 0.002, p=0.968). A chi-square test revealed no significant difference for squat bar position between NCPL (60% low bar, 40% high bar) and CPL (77% low bar, 23% high bar), X^2 (1, n=23) = 0.765, p=0.382). A chi-square test revealed no significant difference for PED use between NCPL (30% used PEDs, 70% did not use PEDs) and CPL (8% used PEDs, 92% did not use PEDs), (X^2 (1, n=23) = 1.958, p=0.162). A chi-square test revealed a significant difference for belt use between CPL (40% used a belt, 60% did not use a belt) and NCPL (92% used a belt, 8% did not use a belt), (X^2 (1, n=23) = 7.304, p=0.007). A chi-square test revealed a significant difference between NCPL (40% used LBex, 60% did not use LBex) and CPL for use of LBex (85% used LBex, 15% did not use LBex), (X^2 (1, n=23) = 4.960, p=0.026).

3. Powerlifting Strength

TABLE 3 HERE

Powerlifting strength values are shown in Table 3. An independent t-test revealed no significant difference for squat 1RM between CPL and NCPL (t(21)=-2.068, *p*=0.051). An independent t-test revealed no significant difference for deadlift 1RM between CPL and NCPL (t(21)=-1.68, *p*=0.108).

4. Isolated Lumbar Extension Strength:

TABLE 4 HERE

ILEX Strength variables are shown in Table 4. A one-way ANCOVA test revealed no statistically significant between group effects for SI, AVG, and MAX values ($F_{(2,52)}$ = 0.195, p=0.824, $F_{(2,52)}$ = 0.280, p=0.757, $F_{(2,52)}$ = 0.564, p=0.572 respectively) when controlling for height, age, stature, mass, and ROM as covariates. The covariate that had a statistically significant effect on SI, AVG and MAX was mass ($F_{(1,52)}$ = 23, p=0.001, $F_{(1,52)}$ = 30, p=0.001, $F_{(1,52)}$ = 65, p=0.001 respectively). Height ($F_{(1,52)}$ = 4.150, p=0.047) had a significant effect on MAX but no statistically significant effect on SI and AVG ($F_{(1,52)}$ = 0.042, p=0838 and $F_{(1,52)}$ = 0.235, p=0.630 respectively). Age did not have a statistically significant effect on SI, AVG and MAX ($F_{(1,52)}$ = 3.064, p=0.086, $F_{(1,52)}$ = 2.472, p=0.122 and $F_{(1,52)}$ = 0.702, p=0.406 respectively). ROM had a significant effect on SI ($F_{(1,52)}$ = 10.313, p=0.002) but no significant effect on AVG and MAX ($F_{(1,52)}$ = 0.390, p=0.535 and $F_{(1,52)}$ = 0.739, p=0.394 respectively).

A one-way ANCOVA test revealed no statistically significant group effects between NCPL and CPL for SI,AVG and MAX ($F_{(1,14)}$ = 0.163, p=0.0.693, $F_{(1,14)}$ = 1.616, p=0.224, $F_{(1,14)}$ = 0.983, p=0.338) when controlling for belt use, PED use, use of LBex, primary deadlift stance, primary squat bar position, squat 1RM and deadlift 1RM. The covariate that had a statistically significant effect on SI, AVG and MAX for the NCPL and CPL groups was deadlift 1RM ($F_{(1,14)}$ = 13.5, p=0.003, $F_{(1,14)}$ = 16, p=0.001 and $F_{(1,14)}$ = 4.73, p=0.047 respectively). Belt use, PED use, use of LBex, primary deadlift stance, primary squat bar position and squat 1RM did not have a statistically significant effect on SI ($F_{(1,14)}$ = 0.199, p=0.663, $F_{(1,14)}$ = 0.621, p=0.444, $F_{(1,14)}$ = 0.020, p=0.889, $F_{(1,14)}$ = 0.040, p=0.843, $F_{(1,14)}$ = 0.292, p=0.597, $F_{(1,14)}$ = 3.618, p=0.078 respectively), AVG ($F_{(1,14)}$ = 0.824, p=0.379, $F_{(1,14)}$ = 0.213, p=0.652, $F_{(1,14)}$ = 0.055, p=0.818, $F_{(1,14)}$ = 0.666, p=0.428, $F_{(1,14)}$ = 0.220, p=0.646 and $F_{(1,14)}$ =

0.512, p=0.486 respectively) and MAX ($F_{(1,14)}$ = 0.045, p=0.835, $F_{(1,14)}$ = 0.001, p=0.971, $F_{(1,14)}$ = 0.036, p=0.853, $F_{(1,14)}$ = 2.006, p=0.179, $F_{(1,14)}$ = 0.366, p=0.555, $F_{(1,14)}$ = 0.359, p=0.558 respectively).

DISCUSSION

The present study investigated ILEX strength in competitive and non-competitive powerlifters, as well as recreationally trained males. There were no significant differences in ILEX strength amongst either group of powerlifters or recreationally trained males despite the differences in habitual prior training. An interesting finding is that both competitive and non-competitive powerlifters were significantly heavier than the recreationally trained participants. When comparing ILEX strength in the 3 groups, the only covariate that had a significant effect on ILEX strength was bodyweight, which suggests that the powerlifting groups were actually relatively weaker than the recreationally trained participants considering that they both had significantly greater body mass.

The results of this study are supported by previous research from Fisher et al. (9) who found that progressively training the RDL did not increase ILEX strength, despite increasing 1RM RDL strength. The absence of a pelvic restraint may explain why the powerlifters' ILEX strength values were no greater than recreationally trained males. The absence of a pelvic restraint may also explain why the competitive powerlifters' ILEX strength values were no different than the non-competitive powerlifters despite using exercises that are designed target the lower back musculature. The deadlift 1RM strength of the powerlifters showed to have significant effect on the SI, AVG and MAX values for the powerlifting groups but since there was no difference between the powerlifter groups and the recreationally trained participants it was probably as a result of stronger individuals being able to score higher on the ILEX strength test. Previous research has suggested that it is necessary for the pelvis to be stabilized in order for the lumbar extensors to be effectively activated and thus properly strengthened (23,5). Powerlifters often perform the deadlift and squat (as well as their derivatives) which are known to elicit significant EMG amplitudes in the lumbar extensors (8,13,4) with high frequency, volume, and load (26),. However, this does not seem to improve ILEX strength. If the powerlifts significantly contributed to ILEX strength it would be expected for competitive and non-competitive powerlifters to have significantly higher SI, AVG and MAX values than recreationally trained males. Indeed, it might also be expected that ILEX strength would be higher in powerlifters, particularly those who are competitive, if ILEX was a key determinant of powerlifting performance. Neither appears to be the case.

Despite the fact that powerlifters evidently do not exhibit greater ILEX strength than recreationally trained males, something which might question its importance for powerlifting performance, previous data has shown that ILEX training can increase RDL 1RM strength. The RDL is not specifically used in powerlifting, though it is sometimes used as an accessory lift in training, yet it may be beneficial for future research to investigate the effect of ILEX training on powerlifting performance. Powerlifters could potentially benefit from ILEX training both in terms of performance as well as in the form of injury prevention. Lower back injuries are common among powerlifters (1,21) and ILEX training is an effective tool in strengthening the lumbar extensors and potentially preventing lower back injuries (1,25). Future research could focus on investigating the effect of adding ILEX training to the training of powerlifters as it could potentially have great implications for improving powerlifting performance and possibly preventing injury. It would be useful to see whether adding ILEX training to a powerlifting program would yield greater increases in deadlift and squat strength than just training the squat and deadlift. Future research could also attempt to compare ILEX strength between powerlifters and strongman competitors to further examine whether ILEX strength can be improved without a restrained pelvis.

The data of this study support existing data on ILEX strength demonstrating the need for pelvic restraint in order to effectively condition the lumbar extensors (24). However, evidently some unrestrained approaches may have the potential to impact the lumbar extensors. Edinborough et al. (5) found that a single set of kettlebell swings was able to effectively fatigue the lumbar extensors regardless of pelvic restraint. Investigating the relationship between free weight exercises such as the kettlebell, or indeed powerlifting style training, and ILEX strength would be useful in finding more cost-effective and accessible solutions for conditioning the lumbar extensors.

The limitations of the present study should be noted. Firstly, this study was cross sectional in design, partly due to the difficulty in recruiting competitive powerlifters to participate in a training intervention study. Often competitive populations are reluctant to forgo their existing training in lieu of performing that prescribed by investigators in a study. Further, though the RECT group was free from low back pain, this was not an exclusion criteria for the CPL and NCPL groups as doing so would have considerably affected the ability to recruit these populations. No participants in the CPL and NCPL groups were suffering from current low back injuries, yet the lack of differences may have been impacted by prior lumbar injuries in the CPL and NCPL groups. Lastly, CPL and NCPL participants were significantly heavier and had a smaller ROM that the RECT participants. This may have impacted strength comparisons particularly as a reduced ROM will impact calculation of the SI (area under the torque curve). Descriptively, SI was lowest in the NCPL and CPL groups, yet AVG and MAX values, were higher. Despite these differences though, when controlled for as covariates, there were still no significant differences amongst the three groups for any strength measure. Another limitation that must be noted is that powerlifting participants were not asked to provide the specific exercises they used to target the lower back musculature. Despite the absence of differences in ILEX strength between the NCPL and CPL group, it would have been insightful to know which exercises powerlifters utilized to target the lower back musculature.

In conclusion, the present data shows that ILEX strength does not differ between competitive and non-competitive powerlifters, and recreationally trained males. This suggests that powerlifting style training likely does not impact upon ILEX strength, despite the use of multi-joint exercises that heavily involve the posterior chain musculature. This also suggests that LEX strength may have little importance for powerlifting performance. However, future work should employ training interventions to both examine the impact of powerlifting style training upon ILEX strength, as well as the effects of increasing ILEX strength upon powerlifting performance.

Practical Applications:

There is currently little evidence showing that progressively increasing strength in the powerlifts, especially the squat and deadlift, will increase lumbar extensor strength. Further, research suggests that most forms of training that do not restrain the pelvis likely are sub-optimal for conditioning the lumbar extensors. As such, though effective in developing strength in the specific lifts, coaches and exercise professionals should at present not prescribe nor promote the squat and deadlift, as well as their derivatives, as effective exercises to strengthen the lumbar extensors. It is unclear the exact impact that specifically training the lumbar extensors has upon powerlifting performance itself. However, if a goal is to specifically target and attempt to strengthen the lumbar extensors, powerlifters may benefit from including specific ILEX training. Powerlifters may also benefit from including kettlebell swings to their training but further research is required to properly understand the effect kettlebell swings may have on lumbar extensor strength.

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FIGURE LEGEND

Figure 1 – MedX Lumbar Extension Machine restrain system

FIGURE(S)

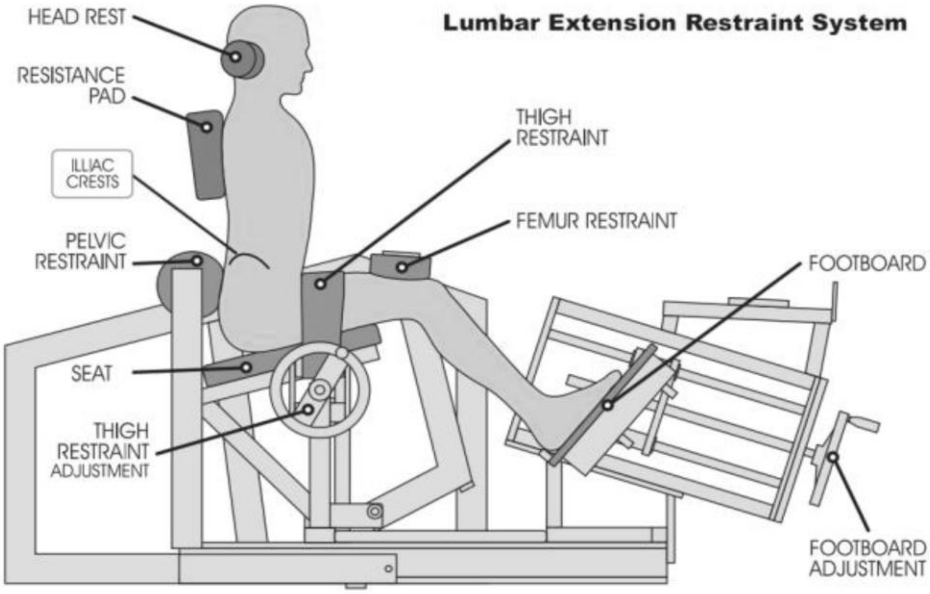

Figure 1 – MedX Lumbar Extension Machine restrain system

TABLES

Table 1 - Participant Characteristics

Characteristic	NCPL (*n* = 10)	CPL (*n* = 13)	RECT (*n* = 36)	*p* value
Age (years)	24±3.5	31.9±7.6	25±6.5	0.003
Stature (cm)	179.2±4.8	173.4±5.5	178±5	0.008
Body mass (kg)	92.39±15.73	91.75±18.7	81.6±10	0.003
Range of motion (degrees)	64.80±8.5	61.85±8.2	71.33±2.7	0.001

Note: Results are mean ± SD

Table 2 - Powerlifting Characteristics

	Group				
PL Characteristic	NCPL (n=10)	CPL (n=13)	X^2	*p*	*df*
Deadlift stance					
Conventional	n=7	n=9			
Sumo	n=3	n=4			
Chi Squared Tests			0.002	0.968	1
Squat bar position					
Low bar	n=6	n=10			
High bar	n=4	n=3			
Chi Squared Tests			0.765	0.382	1
Belt					
Use a belt	n=4	n=12			
Do not use a belt	n=6	n=1			
Chi Squared Tests			7.304	0.007	1
PEDs					
Use PEDs	n=3	n=1			
Do not use PEDs	n=7	n=12			
Chi Squared Tests			1.958	0.162	1
Lower back exercises (LBex)					
Use LBex	n=4	n=11			
Do not use LBex	n=6	n=2			
Chi Squared Tests			4.960	0.026	1

Table 3 – Powerlifting Strength

Characteristic	NCPL (*n* = 10)	CPL (*n* = 13)	*p* value
Squat 1RM (kg)	177±14	215±12	0.051
Deadlift 1RM (kg)	204±12	232±11	0.108

Note: Results are marginal mean ± SE

Table 4 – ILEX Strength

ILEX Strength Measure	NCPL	CPL	RECT	*p* value
Strength index (N_m)	22864±1478.9	22850±1559.4	23801±836.7	0.824
Average torque (N_m)	345.8±21.09	344.9±22.24	361.6±11.93	0.757
Max torque (N_m)	472.8±24.17	451.7±25.49	485.6±13.67	0.572

Note: Results are marginal mean ± SE