7-WEEKS OF YOGA TRAINING AND ITS EFFECTS ON FLEXIBILITY AND RATE OF FORCE DEVELOPMENT IN OLYMPIC WEIGHTLIFTERS

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Pre- and post-testing was performed consisting of flexibility and rate of force development (RFD) measurements. Participants performed a sit and reach test followed by a loaded overhead squat test with a barbell that was recorded with video to assess joint angles. A countermovement jump and snatch were performed after to measure RFD. Afterwards the participants were split, with the experimental group receiving 7-weeks of yoga training. After 7-weeks participants returned for post-testing and there was a significant difference ($p < 0.05$) within participants for the following variables: sit and reach, shoulder flexion, knee flexion, ankle flexion, countermovement jump RFD, and snatch RFD. There was no significant interaction between the pre/post-test and the condition, or between groups for any variable ($p > 0.05$). Yoga training does not alter weightlifting performance variables.

KEYWORDS: Power, chronic stretching, sit and reach, 2-Dimensional Video

INTRODUCTION: Both men's and women's Olympic weightlifting currently consist of two lifts, snatch and clean and jerk. These are both whole body movements which combine great strength, power, speed, kinesthetic awareness, technique, and flexibility (Fry et al., 2006; Stone et al., 2006). These athletes can lift 2-3 times their body mass overhead during competitions, and have been observed to have the highest power outputs recorded in sport (Fry et al., 2006; Stone et al., 2006).

The overhead squat test (OHS) is a screening tool for weightlifters' flexibility that is extremely sport specific, with the athlete holding a bar overhead and performing a deep squat. The OHS (which can be filmed to measure joint angles and assess any restrictions) has been shown to be a predictor of injury, identifying tight and overactive or weak and underactive muscles, and uncovering joint restrictions (Bell et al., 2012).

Stretching can have an effect on the OHS. If someone is more flexible, the compensations in the OHS will be less apparent or not there. Chronic stretching aims to decrease injury and increase performance by increasing the compliance of the muscle and therefore reducing the energy needed to move the limb (Bazett-Jones et al., 2008). There is still no conclusive evidence that chronic stretching improves performance measures during multi-limb movements, such as rate of force development (RFD) (Bazett-Jones et al., 2008). While chronic stretching is not the same as yoga, both aim to increase flexibility. Yoga has also been shown to increase lower extremity and low back flexibility significantly more than static stretching over the same period (Tekur et al., 2008).

To our knowledge there are few studies that examine force or power production over an extended period of any form of stretching (Bazett-Jones et al., 2008). There is currently no research focusing on chronic yoga training in Olympic weightlifters and how it will affect their flexibility and RFD. The purpose of this study was to determine what effects 7-weeks of yoga training had on Olympic Weightlifters' flexibility and RFD.

METHODS: Participants were 18 Olympic Weightlifters, 10 males and 8 females, currently training for competition at the Olympic Training Site at Northern Michigan University (Mean $\pm$ SD: age = 19.28 y $\pm$ 1.41; height = 167.0 cm $\pm$ 7.52; mass = 75.71 kg $\pm$ 22.48; Sinclair score = 259.85 $\pm$ 64.13; years of training = 4.42 y $\pm$ 3.29). They had no surgery in the previous six months, were physically able to perform a snatch, and could not have practiced yoga regularly over the past six months (once a week for longer than one month). All experimental procedures were approved by the Institutional Review Board before the study commenced (HS15-685). Participants completed an informed consent, Physical Activity Readiness-Questionnaire, and 24-hour dietary survey before any testing was performed.

Before yoga training began, baseline measures were determined. Participants were fitted with reflective markers on the right side of the body, as well as a lateral point on the barbell (Fry et al., 2006; Norris & Olson, 2011). After marker fitting, participants rode a stationary bike for five minutes as a warm up (Bell et al., 2012). All testing was performed after the warm up in the following order: Sit and reach (SR) test, OHS, vertical jump, and snatch lift.

The SR test was performed using a custom built device; participants sat with legs extended, bare feet flat against the SR device, exhaled and stretched forward as far as possible. This was repeated three times with the greatest range of motion (ROM) used for analysis. This protocol has been used to determine flexibility in other studies and has been found to be highly reliable (Behm et al., 2012; Donahoe-Fillmore & Brahler, 2009).

The loaded OHS was performed next and recorded with 2-dimensional video (Casio EX-ZR10, Casio America Inc., Dover, NJ) in the sagittal plane from four meters away at 60 Hz. Each subject performed the OHS with an Olympic barbell (determined by their sex) in bare feet; the feet were shoulder width apart, toes pointed straight forward, heels on the floor, arms overhead with the hands shoulder width apart, and elbows extended (Bell et al., 2012). This was performed three times and the mean values for shoulder, hip, knee, and ankle angles were determined. All joint measurements were made in degrees and determined using MaxTRAQ 2D software (Innovision Systems Inc, Columbiaville, MI, USA); 2-dimensional video has been validated to accurately measure joint angles for this task (Norris & Olson, 2011).

Participants then performed two countermovement jumps (CMJ) on twin force platforms (OR6-2000 Advanced Mechanical Technology, INC. [AMTI], Watertown, MA), which collected data at 1000 Hz, to determine RFD. The greatest RFD produced during the jumps was analyzed and averaged over a 100 ms moving window (Aagaard et al., 2002). A 60 second break was given between attempts to reduce the possibility of fatigue. The participants were instructed to jump as high as possible immediately following a counter movement (Behm et al., 2012).

Finally, the participants warmed up over 10 minutes to lift 80% of their 1RM snatch attained in competition. Two minute rest period between attempts was given to reduce the possibility of fatigue. The trial which produced the greatest RFD was analyzed, and 80% of 1RM was chosen as this has been shown to be the optimum percentage to reach peak RFD (Stone et al., 2006).

After initial testing, participants were randomly divided into experimental (n=9) and control (n=9) groups, controlled for sex. The experimental group completed ten, one hour sessions of hatha yoga over 7-weeks. The control group did not perform the asanas (postures), but did participate in meditation and centering. While the experimental group performed asanas, the control group watched videos relevant to weightlifting culture. All participants maintained their current activity level through the training period and were on similar training cycles. Ten sessions of yoga training was determined to be a sufficient dose response to increase flexibility (Donahoe-Fillmore & Brahler, 2009). The class consisted of hatha yoga which combines asanas for strength and flexibility, and breathing techniques.

After 7-weeks of yoga training, participants performed the same surveys, paperwork, and tests in the same order as previously. They were instructed to consume the same diet 24 hours before testing as during the pre-test situation and all participants performed their testing at the same time of day as during their pre-test.

A 2x2 mixed ANOVA (group X pre/post) was used to determine significance with a confidence interval of $p = .05$. Effect sizes are reported using Cohen's D, and were based on the scale for effect size classification of Hopkins (2002). This scale is based on f-values for effect size and the scale for classification is as follows; <0.04 = trivial, 0.041 to 0.249 = small, 0.25 to 0.549 = medium, 0.55 to 0.799 = large, and >0.8 = very large. Seventeen participants completed the entire study and their data were used for analysis. One male participant dropped from the study, and one male participant was unable to perform post-test snatch due to injury.

RESULTS: The participants' means and standard deviations for the variables of interest are shown in Table 1. There was a significant difference ($p < 0.05$) comparing the pre-test and post-test values for all variables except hip flexion (Table 1). There was no significant interaction ($p > 0.05$) between the pre- and post-test and the condition and all effect sizes were trivial or small. No significant difference ($p > 0.05$) was found between experimental and control groups for any variable and effect sizes were all small or trivial. (Table 1).

Table 1. Means (SD) for the variables of interest, and the effect sizes for between groups analysis.

Test	Group (N)	Pre (SD)	Post (SD)	ES
Sit and Reach [a] (cm)	Exp (9)	27.72 (5.55)	26.06 (7.30)	.101
	Control (8)	32.13 (5.92)	29.63 (6.93)	
Shoulder Flexion [a] (degrees)	Exp (9)	189.31 (5.99)	186.49 (8.15)	.009
	Control (8)	188.96 (7.47)	184.43 (7.33)	
Hip Flexion (degrees)	Exp (9)	106.16 (19.82)	118.48 (13.20)	.026
	Control (8)	115.25 (17.07)	118.71 (18.46)	
Knee Flexion [a] (degrees)	Exp (9)	118.73 (17.22)	127.72 (14.56)	.002
	Control (8)	118.96 (19.00)	124.65 (20.57)	
Ankle Dorsiflexion [a] (degrees)	Exp (9)	89.69 (8.23)	101.38 (7.99)	.023
	Control (8)	94.70 (12.73)	100.79 (9.21)	
CMJ RFD [a] (N/s)	Exp (9)	11165.12 (3341.20)	10629.25 (3021.24)	.002
	Control (8)	10914.94 (3729.23)	10386.84 (3181.6)	
Snatch RFD [a] (N/s)	Exp (9)	8633.86 (2629.12)	7918.55 (1839.03)	.003
	Control (7)	8304.27 (2157.25)	7777.08 (2201.24)	

[a] denotes significance at the .05 level for within-subjects means. CMJ = countermovement jump, RFD = rate of force development, Exp = experimental, ES = effect size between groups

DISCUSSION: The current study examined the effects yoga training had on Olympic Weightlifter's flexibility and RFD. We hypothesized that weightlifters would increase their flexibility as demonstrated by the SR test and the OHS, and increase their RFD. This did not occur with the results of our study. While there was a significant difference within subjects pre- and post-tests for all variables except hip flexion, there were no significant differences found in any measure between groups from the pre- to post-test.

While there have been no studies examining the effects of yoga training on RFD, there have been many studies that examine yoga's effects on flexibility and ROM. Studies have shown that yoga increases participants SR scores in as little as six sessions over six weeks (Donahoe-Fillmore & Brahler, 2009). Yoga has also been shown to increase flexibility greater than static stretching (Tekur et al., 2008). There are two primary areas which show the greatest increase in ROM after performing yoga training, these are the lower back (Tekur et al., 2008) and knee joint (Ghasemi et al., 2013). The results of our study demonstrated that both groups had significantly decreased scores on the SR test. The difference between our study and previous yoga studies could be the activity level of the populations studied. Our participants routinely participated in Olympic weightlifting four to six days a week, which requires total body flexibility to complete a lift (Fry et al., 2006).

The same participants significantly increased their ROM at the knee and ankle during the OHS. While shoulder ROM did decrease in both groups from the pre- to post-test, an increase in knee and ankle ROM probably caused a decreased need for hyperflexion during the OHS to maintain their balance. Adelsberger and Tröster (2014) demonstrated that an individual with great lower extremity ROM would place less torque on the shoulder during an OHS, requiring less shoulder flexion. This change in ROM leads to a more upright posture in the bottom position, and more stability during the catch, where most lifts fail.

Behm et al. (2006) and Guissard and Duchateau (2004) both found that after chronic stretching there was an increase in ROM for the area's stretched. Behm et al. (2006) specifically found a significant increase in the participants SR scores after four weeks of lower extremity stretching. However, Bazett-Jones et al. (2008) found that Division III female track athletes did not have a significant increase in ROM after a six week chronic stretching protocol, which is similar to our findings. Bazett-Jones et al. (2008) theorized that participants did not increase their ROM because the athletes had already reached their "optimal" ROM for their sport.

The primary reason why stretching would increase RFD is that chronic stretching increases the compliance of the muscle, which would require less energy to use the muscle (Bazett-Jones et al., 2008). In a review by Shrier (2004) there was evidence that single joint motions show increases in isometric peak force and velocity of contraction after chronic stretching, but multi-joint movement research has demonstrated that there is little performance enhancement. Our study showed that yoga training did not alter RFD for the CMJ or snatch between groups. This agrees with other studies that have shown, after chronic stretching, there were no changes in RFD, velocity of contraction, or max force production (Bazett-Jones et al., 2008; Behm et al., 2006; Guissard & Duchateau, 2004). While there was no increase in any of the performance measures, there was also no significant decrease. This is because with chronic stretching there is only an increase in stretch tolerance and not visco-elasticity (Shrier, 2004).

Our study had the following limitations. The participants were on similar training cycles but were not on the exact same cycle. This leads to slight differences in training volume and intensity. Another limitation could be that more training sessions or a longer training period may have been needed to see the effects yoga had on Olympic weightlifting.

CONCLUSION: Yoga training did not demonstrate any significant differences between groups for the SR test, OHS test, and RFD during a CMJ and snatch. While there was a decrease in SR scores within subjects, ROM increased during the OHS for the knee and ankle, which can lead to a more stable catch position. Based off our findings Olympic weightlifters can participate in chronic yoga training without causing significant decreases in performance. Future studies should continue to examine the effects of chronic stretching and yoga on performance variables in a variety of sports.

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