Changes in Loaded Squat Jump performance following a series of isometric conditioning contraction

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Abstract

Aim:

The aim of this study was to investigate the effects of performing an isometric conditioning contraction (CC) consisting of two sets of five seconds maximal voluntary contraction in physically active individuals prior to three sets of Loaded Squat Jumps (LSJ).

Method:

5 males and 4 females (mean ± SD: age 25 ± 2 years, height 175 ± 10 cm, body mass 70 ± 15 kg) were assessed on their power output, force production, jump height and velocity on three sets of LSJ on two separate sessions. Each participant attended two sessions in randomized order: a control session (CON) and an experimental session (EXP) separated by at least two hours. The EXP session consisted of a 10 min warm-up followed by 2 x 5 seconds isometric CC, this was proceeded by another two minutes of rest before three sets of LSJ were performed, each set separated by a two-minute rest. During the CON session a two-minute rest, followed by three sets of LSJ, replaced the isometric CC sequence.

Results:

No significant improvement was found on any of the physical parameters assessed, comparing the CON and EXP session ($p > 0.05$). The results showed a variance on individual response were some subjects performed better after the CC and others did not .

Conclusion:

In conclusion, this study evaluated the effect of performing an isometric CC prior three sets of LSJ. The results indicate that an isometric CC consisting of two sets of five seconds maximal voluntary contraction is insufficient to enhance the performance in an LSJ.

Sammanfattning

Syfte och frågeställningar:

Syftet med denna studie var att undersöka effekterna av en serie av isometriska muskel kontraktioner (CC) bestående av två set av fem sekunders maximal isometrisk kontraktion i fysiskt aktiva individer innan tre set av Loaded Squat Jump (LSJ).

Metod:

5 män och 4 kvinnor (medelvärde ± SD: ålder 25 ± 2 år, höjd 175 ± 10 cm, kroppsvikt 70 ± 15 kg) testades på deras effektutveckling, kraftproduktion, vertikal hopphöjd och hastighet vid utförandet av tre set av LSJ vid två separata testtillfällen. Varje deltagare deltog vid ett kontroll tillfälle (CON) och ett experiment tillfälle (EXP) med minst två timmar mellan. EXP tillfället bestod av en 10 min uppvärmning följ av en 2 x 5 sekunders isometrisk CC följt av en två minuters vila innan tre LSJ försök. Varje försök genomfördes med två minuters vila. CON bestod endast av en 10 min uppvärmning med en sex minuters vila efter, samt följt av tre set med LSJ.

Resultat:

Ingen signifikant förändring upptäcktes på någon av de fysiska parametrarna mellan de två olika testtillfällena CON och EXP session ($p > 0.05$). En stor individuell variation kunde ses avseende effekten av CC

Slutsats:

Studien utvärderade effekten av att utföra en isometrisk CC före tre set av Loaded Squat Jump (LSJ). Effekten av en isometrisk CC bestående av två set av fem sekunders maximal frivillig isometrisk kontraktion är inte tillräckligt för att förändra prestationen i en LSJ.

Index

1 Introduction 1

2 Background 2

3 Aim and research questions 6

4 Method 7

4.1 Participants 7

4.2 Study design 8

4.2.1 Warm-up 8
4.2.2 Experimental session 9
4.2.3 Control session 9
4.3 Performance measurements 11

4.3.1 Loaded Squat Jump 11
4.3.2 Conditioning Contraction and Rate of Force Development 11
4.4 Procedures 12

4.5 Statistical Analyses 13

4.6 Validity and reliability 14

4.7 Ethical consideration 14

5 Results 15

5.1 Power output 16

5.2 Force production 17

5.3 Jump height 18

5.4 Velocity 19

6 Discussion 20

6.1 Methodological considerations 23

6.2 Conclusion 25

7 Practical applications 25

8 Reference list 26

10 Appendix 31

10.1 Informed consent 31

10.2 Literature search 32

1 Introduction

Warm-up is a common practice and part of many athletes normal routine prior to training and competition. Warm-up enhances performance relative to that which would have been expected if the warm-up was not completed. To this day warm-up is considered to provide both physiological and psychological benefits prior to competition (Bishop, 2003). Warm-up refers to a series of physical exercises designed to gradually increase heart rate, circulation, muscle temperature and joint/tendon mobility prior to commencing specific training regimes or competition, effects that are known to optimize performance (Bishop, 2003; Yaicharoen, Wallman, Bishop & Morton, 2012).

Another important aspect of sport performance, especially in power sports such as sprint running and sports involving vertical or horizontal jumps (e.g. basketball/ track and field) is the ability to develop high muscle power output. These sports are dependent on the ability to produce high power, but also on the athlete's ability to perform work over a short time interval. Power is defined as the amount of work performed during a specific time (Power (W) = force x distance/time). Peak power (PP) is the highest power value found over a range of motion under a given set of conditions. Another important factor is Rate of Force Development (RFD) which is associated with explosive strength and is directly related to the ability to accelerate objects, including body mass (Marques, 2010). Thus, a greater RFD capacity can increase the ability to accelerate.

Over the past decade a new element has been integrated into warm-up protocols, known as conditioning contraction (CC). CC refers to performing a muscular voluntary contraction (MVC) prior to performance. This is usually performed at a submaximal or near maximal effort. Research have shown that performing a CC will improve the ability to increase both PP and RFD in short period Docherty & Hodgson, 2007; Esformes, Keenan, Moddy & Bambpouras, 2011), which may in turn improve an athlete's explosive movements. However, to date there are conflicting findings with regard to the benefits of CC, and how the CC should be performed (Tillin & Bishop, 2009).

2 Background

Previous research in the field on CC has demonstrated both significant and no significant improvement in explosive movements. McBride, Nimphius & Erickson (2005) showed that one set of squats with three repetitions at 90 % of the subject's one repetition maximum (1RM), on 15 elite soccer players, increased the running speed on 40 m sprint with 0.87 % ($p = 0.01$). Rahimi (2007) demonstrated that two sets of four repetitions with heavy-squats (85 % of 1RM) prior to sprint running, significantly improved the running speed in twelve elite soccer players. In addition, three different types of CC protocols (60% of 1RM, 70% of 1RM, 85% of 1RM) improved running speed, with the greatest improvement (-2.92%) found with 85 % of 1RM (Rahimi, 2007). Several other studies have also demonstrated that squats with heavy-loads prior to explosive movements will enhance performance (Clark, Bryant & Reaburn, 2006; Chatzopoulos, Michailidis, Giannakos, Alexiou, Patikas, Antonopoulos & Kotzamanidis, 2007; Yeter & Moir, 2008). A study by Chatzopoulos et al. (2007) presented a significant improvement on 30 m sprint following ten single squat repetitions at 90 % of 1RM. When comparing the results from the previous mentioned studies, the biggest improvements were found using heavy-loads (< 5RM or ≥ 85% of 1RM). The authors concluded that for athletes to induce the optimal enhancement of running speed it is necessary to set the intensity of the CC with high-dynamic load intensitites.

Sprint and high-intensity intermittent efforts are common in ball and racket sports. These sports involve short sprints, deceleration and acceleration and change of direction, known as Repeated Sprint Ability (RSA). A recent study written by Okuno, Tricol, Bertuzzi, Moreira & Kiss (2013) demonstrated that a CC enhanced 15 elite handball players performance in RSA five minutes after a dynamic squat CC. The CC was performed as one set of 5 x 50 % 1RM, one set of 3 x 70% 1RM and five sets of 1 x 90% 1RM. Even if the results showed a small to moderate change, the findings of Okuno demonstrate that the effects of a CC is not only present once, but may be sustained over a longer time. Studies have also reported that a CC will enhance performance on upper body. For example, a study written by Kilduff, Bevan, Kingsley, Owen, Benett, Bunce & Cunningham (2007) presented that peak power output (PPO) was significantly improved 8 – 12 minutes after CC in lower body and after 12 minutes in upper body in 23 professional rugby players. Each session contained a warm-up, baseline test **(**countermovement jump (CMJ) or ballistic bench throws**)** and a preload stimulus (3RM squats or 3RM bench press). Each participants performed CMJ or a ballistic bench throw immediately after the CC and at every following 4 minutes, uptil 20 minutes. To date their is still no consensus about what the optimal recovery period is after a preload stimulus (CC). Previous research have reported a range between 1-18 minutes when it comes to the optimal recovery period after performing a CC (Young, Jenner & Griffiths, 1998; Dutchie, Young & Aitken, 2002; Chiu, Fry, Weiss, Schilling, Brown, & Smith, 2003; Gourgoulis, Aggeloussis, Kasimatis, Mavromatis & Athanasis, 2003; Hilfiker, Hubner, Lorenz & Marti, 2007; Brandenburg, 2005; Bevan, Cunningham, Tooley, Owen, Cook & Kilduff, 2010; Macintosh, Robillard, & Tomaras, 2012; Wilson, Duncan, Marin, Brown, Loenneke, Wilson, Lowery & Ugrinowitsch, 2012).

Another inconsistency regarding the benefits of CC is the strength of the participants used in the studies. Previous research report that the benefits of a CC is greater in participants who demonstrate a greater absolute strength and have a longer strength training background. For example, Young et al. (1998) demonstrated that participants with greater absolute strength will improve their jump height more then individuals with less absolute strength followed by a CC. More recent studies have replicated such results (Dutchie, 2002; Gourgoulis, 2003 & Chiu 2003). A study written by Rixon, Lamont & Bemben (2007) presented a significant improvementon jump height and power output in individuals with previous weightlifting experience, compared to individuals with no weightlifting experience, after performing both a dynamic and isometric CC. These results are in line with the findings of Clark et al. (2006) and Chatzopoulos, Michailidis, Giannakos, Alexiou, Patikas, Antononpoulos & Kotzamanidis (2007). With regard to these results the benefits of a CC is likely to be most effective in individuals with a high strength level or a greater proportion of fast twitch muscle fibers.

It has been postulated that the biomechanics of a CC should be similar and performed as a dynamic exercise to those of the performance task. In contrast, some studies have demonstrated that performing a maximal isometric muscular contraction as a CC improves the performance (Gullich & Schmidtbleicher, 1996; French, Kraemer & Cooke, 2003; Rixon et al. 2007; Esformes et al. 2011; Feros, Young, Rice & Talpey, 2012). Rixon et al. (2007) presented that a muscular isometric squat (three attempts each three seconds long with a two minute rest between) improved jump height and power output more than performing a dynamic squats in individuals with weightlifting experience (two reps x 50 % of 3RM, one rep x 85 % of 3 RM, one set of 3RM). A more recent study written by Feros et al. (2012) demonstrated that maximal isometric muscular contractions prior performance significantly improved the power output on a 1000m time trial following a 5 x 5 seconds maximal isometric contraction. Their result showed a significantly improved power output and time over the first 500 m ($p < 0.01$), but no significant improvement on time after 1000 m (0.9% $p > 0.05$). The authors concluded that adding isometric CC to the warm-up may allow for a greater power output in the start of the race to faciliate greater acceleration. The studies mentioned above investigated if an isometric CC is more efficient than dynamic CC. The results demonstrated that only an isometric CC improved on vertical jump and PPO compared to a dynamic CC (Rixon et al. 2007; Esformes et al. 2011). Esformes et al. (2011) suggests that an isometric CC induces a longer PAP period (>12 min). The aforementioned studies have no explanation for why the PAP is induced longer at an isometric CC. Regardless of what causes a longer effect from an isometric CC it might be a practical application in sports involving prolonged resting periods, but still this is only postulations and merits further research.

Countermovement jump (CMJ) or jumps squat (JS) is a common training practice among athletes to improve their jump height for example Basketball. CMJ and JS are also normally used in studies aimed at evaluating strength and power performance parameters, such as PP and RFD (Clark et al. 2006; Hilfiker et al. 2007; Lima, Marin, Barquilha, Da Silva, Puggina, Pithon-Curi & Hirabarai, 2011; Crewther, Kilduff, Cook, Middleton, Bunce & Yang, 2011), in contrast, studies have also demonstrated no significant improvent in CMJ following a CC (Mcbride, 2005; Till & Cooke, 2009). For example, Hilfiker et al. (2007) presented a result that demonstrated a signficant improvement on CMJ and JS height following five modified drop jumps one minute after in athletes with high capacity of producing high explosive force. A more recent study (Lima et al. 2011) found a significant improvement in 10 male athletes five minutes after a CC (2 sets of 5 drop jumps) on CMJ height and on 50 m sprint time. In contrast, Till & Cooke (2009) demonstrated no significant improvement on sprint time and jump height on different rest intervals (4, 5, 6 min post CC) after performing two different type of CC (MVIC, 5 x 5 RM deadlift) on elite active fotball players.

CC is assumed to increase the phenomenon known as Postactivation Potentiation (PAP). PAP refers to the phenomenon in which acute muscle force output is enhanced as a result of contractile history. It has been postulated that explosive movements may be enhanced if preceded by heavy resistance exercise. The responsible mechanisms behind PAP are yet to be elucidated. It has been proposed that there are two responsible mechanisms contributing to PAP, these include phosphorylation of myosin regulatory light chains (LRC) and increased recruitment motor units (Tillin & Bishop, 2009). If PAP has been observed, the biological mechanisms/pathways involved in PAP will theoretically increase both PP and RFD that might improve an athlete’s explosive movements.

The previous research regarding CC has mostly investigated the effects on elite active. To our knowledge few studies have investigated the effects of CC on non-elite active individuals. Furthermore, the benefits of shorter rest periods on enhancing explosive performance have also not been assessed.

3 Aim and research questions

The aim of this study was to investigate the effects of performing an isometric conditioning contraction on physically active individuals prior three sets of LSJ. The specific research questions were:

- Will a CC involving two sets of five seconds maximal voluntary isometric contractions improve performance in a LSJ?

4 Method

4.1 Participants

Inclusion criteria for the study were as follows:

- > Eighteen years
- Physically active for at least 3-5 day/ week
- At least one year of experience from resistance training
- Have been or still is active in organized training or competition
- Free from injuries for at least 6 months prior the study

Five males and four females agreed to participate in this study (mean ± SD: age 25 ± 2 years, height 175 ± 10 cm, body mass 70 ± 15 kg) (Table 1). All participants were physically active at least 3-5 days a week. Some of them were still active athletes, and all had experience from competing and training in different sports. All subjects had experience of resistance training, but few had specific experience of weightlifting experience. All participants were free of injuries at the time of the study for at least six months. All participants were instructed to refrain from any intense activity 24 hours before each session and from drinking diuretic beverages and alcohol before each testing day at the laboratory. Every participant had been notified about the study design and the tasks they would be requested to perform and written informed consent was obtained from all subjects.

Table 1. Characterization of the participants according to the following variables age, height and weight. Participant's individual values and the participants combined mean ± SD of each variable.

Participant	Age (year)	Body mass (kg)	Height (cm)
1	26	92	186
2	28	87	189
3	26	58	167
4	24	70	177
5	24	59	173
6	27	67	176
7	22	63	160
8	28	48	167
9	23	86	184
Mean ± SD	25 ± 2	70 ± 15	175 ± 10

4.2 Study design

The investigation was performed as a crossover randomized design involving three sessions on two different days. The first session was performed as a familiarization session at day one. At the familiarization (FAM) the participants had the chance to test the equipment and become comfortable with its use. Their weight and height was measured and their isometric maximal strength (ISO_{max}) and RFD was measured as well (described later in text). The following day, two different sessions were executed with at least two hours between each session. One session was performed as the experimental session (EXP) and the other one as a control session (CON). Participants were randomly assigned which session type they should start with. A researcher oversaw the procedure and made sure that each session was performed correctly at each attended session.

4.2.1 Warm-up

The warm-up was performed on a Monark ergometer bike (Monark Ergomedic 828E, Sweden, Vansbro) with a resistance of 1.5W/ kg. The participants were instructed to pedal at a cadence at 70 rpm. The duration of the warm-up was 10 minutes.

4.2.2 Experimental session

Experimental (EXP) session involved a warm-up, an isometric CC and three sets of Loaded Squat Jump (LSJ), each set consisting of three repetitions. A four-minute rest followed the warm-up. The CC was performed in a vertical position, with an angle of 90° degree in the knee joint, measured with a goniometer, described later in the text as ISO_{max}. Participants performed a maximal isometric condition contraction 2 x 5 seconds with 15 seconds rest between. During the maximal isometric contraction the participants received verbal encouragement. A two-minute rest was adopted after the CC (Figure 1) followed by a three sets LSJ, as described later in the text.

4.2.3 Control session

The control session (CON) involved a warm-up, followed by a four-minute rest then an additional two-minute rest (Figure 1). After the additional two-minute rest three sets of three repetitions of LSJ was performed, as described later in text.

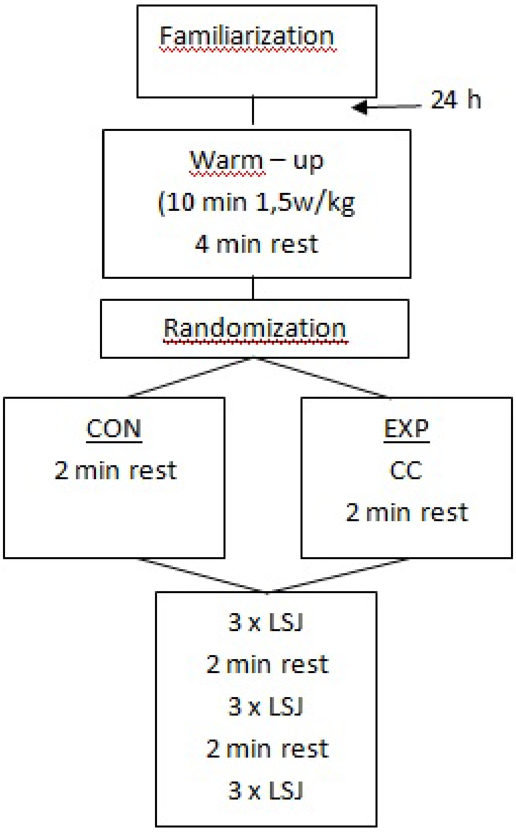

Figure 1. Flow diagram of the study design. CON = Control session; EXP = Experimental session; CC = Conditioning Contraction; LSJ = Loaded Squat Jump.

4.3 Performance measurements

4.3.1 Loaded Squat Jump

After the CC in the EXP session, and after the two-minute rest in the CON session each participant executed three sets of Loaded Squat Jump (LSJ) with a barbell weight of 40 kg suspended in a Smith-machine (Cybex International Ltd, United Kingdom). Each set consisted of three repetitions. A rest of two minutes followed each LSJ set (Figure 1). During the jumps, security locks were placed on the Smith machine at a pre-measured knee position of 90° to prevent the eccentric movement in the squat being performed lower than 90°. A vertical displacement linear encoder (Muscle Lab, Ergotest Technology AS, Norway) was used to enable calculation of power output in each lift. Data was only collected in the concentric phase of each LSJ attempt. This linear encoder made it possible to collect data regarding the jump height and velocity of the bar and also the amount of force and power produced in the concentric phase. With the use of this exercise it was possible to assess if there had been a significant increase between the CON and EXP session. The variables power output (W), force production (N), jump height (cm) and velocity (m/s) where analyzed.

4.3.2 Conditioning Contraction and Rate of Force Development

The CC used in this study was a maximal isometric voluntary contraction (MIVC). During the familiarization (FAM) session each participant performed a maximal isometric voluntary contraction (MIVC). This type of exercise was used as the CC and was performed both in the FAM session (ISO_{max} - FAM) and EXP session (ISO_{max} – EXP). The purpose of this exercise was to determine their isometric peak power (ISO_{max}) and their RFD. Each participant was given three attempts to achieve their best result. The data from the best attempt were later used to determine if they reached their maximum capacity at the EXP session. The RFD data was measured at 50 ms, 100 ms, 150 ms and 200 ms and was measured at each attempt. This exercise was executed by using a vest attached to a chain in conjunction with a goniometer, the chain was adjusted to a length that matched an angle of 90° degrees in the knee joint.

The other end of the chain was connected to a receiver (Nobel elektronik Bkl - 5 AB, Karlskoga, Sweden), which was attached to a wooden plate (Figure 2). With the use of this receiver it was possible to measure RFD and the ISO_{max} performed at both FAM and EXP session. With the use of a computer software, the data from the receiver was later analyzed.

Figure 2. The apparatus and participant position used when performing the conditoning contraction. This was also used to determine the participant's RFD and peak power when performing the ISO_{max} at the familiarization (FAM) session and experimental (EXP) session.

4.4 Procedures

The first day contained the FAM session where the participants were informed about the study design and a written informed consent was obtained from the participants (Appendix 1), their weight and height was also measured. Each participant were assigned a number to preserve anonymity. The participants began their warm-up followed by a four minute rest. During the rest the vest was put on and while they where in a seated position the chain was attached to the west and to the wooden plate. With the use of a goniometer the length of the chain was adjusted to a length that matched an angle of 90° degrees in the knee joint. Participants had one test attempt before the following three ISO_{max} attempts. Participants received a ten-second and five-second notice before the first attempt. With five seconds left the participants were instructed to stand in the starting position (90°) and the researcher began a countdown (5, 4, 3, 2, 1) followed by the maximal isometric voluntary contraction (ISO_{max}). A total of three attempts were executed with a 5 – 10 second rest between each attempt. Participants received verbal feedback on what they could improve after each attempt. When all three attempts were completed each participant received feedback regarding their ISO_{max} as presented on a computer monitor. Data was collected from the three attempts and was analyzed before their EXP session.

After the ISO_{max}-test participants were then moved to the Smith machine where their LSJ tests were carried out. The researcher demonstrated the correct technique for the exercise and the participants had several attempts of testing the exercise without and with the resistance of 40 kg. After each attempt the researcher gave feedback on what could be improved regarding their technique. After the researcher had seen several correctly executed attempts a FAM session was completed. No data was collected during the three sets of LSJ attempts at the FAM session.

The following day participants arrived at the laboratory for another two sessions, the CON or the EXP session with at least two hours between. Participants were randomly assigned to their starting session i.e. CON or EXP. The CON and the EXP session were executed as described earlier in text.

4.5 Statistical Analyses

All results are reported as mean ± standard deviation (SD). A 2-tailed dependent student t-test was used to test for significant changes on all dependent variables which are power output, force production, jump height and velocity. A total of three attempts were performed in the LSJ sets. Repeated 2-way variances of analysis (ANOVA) were also used to determine changes on each variable between the CON and EXP session. The best attempt at each set was analyzed for significant changes between the CON and EXP session. The alpha value was set to 0.05. All statistical analysis was performed by using Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA) and Statistica 64 (Version 11, StatSoft. Inc. 2012, USA, Tulsa)

4.6 Validity and reliability

The equipment used in this study at GIH (Swedish school of health and sports sciences) is regularly calibrated by qualified technicians to ensure accurate measurements for all tested parameters. The average power production in the concentric part of the LSJ is calculated by using the velocity and the displacement of the mass being moved with the suspended barbell. The validity of the linear encoder has previously been tested by moving the barbell ten times over a premeasured distance of 31.5 cm on two different occasions. Each occasion for the validity test was separated by 48 hours and correlating this to the output information given by the Musclelab program of the computer. The mean and standard deviation results from the Musclelab program was 31.53cm ± 0.08 cm making the correlation very high ($R = 0.999$) thus validating this parameter (Swedish National Sports Complex).

4.7 Ethical consideration

All participants were informed about the study. Each participant read and signed the informed consent (Appendix 1). Participants were included in the Swedish insurance system which covered any potential patient costs. The study was accepted by the ethics committee at the Swedish School of Sports and Health Sciences (GIH). The study contained exercises which some participants had never experienced before and perhaps felt a little bit uncomfortable with when performing each exercises. Therefore, a familiarization session where included in the study. The sampling methods contained only physical stress that could lead to fatigue and muscle soreness.

5 Results

All sessions where completed for each participant without failure or injury. Participants ISO_{max} were significantly higher with an increase of 20 % from the FAM session to the EXP session (ISO_{max}: 1556 ± 790 N versus 1820 ± 969 N, $p < 0.05$) (Table 2). RFD showed no significant improvement between the FAM session and EXP session ($p > 0.05$). These results indicate that each participant at least reached their maximum value when performing the ISO_{max} in the EXP session (Table 2).

Table 2. Each participants best ISO_{max} (N) at both the familiarization (FAM) session and at the experimental (EXP) session (CC). * A significant difference between the FAM and the EXP session ($p < 0.05$). Each participant's individual value and their total mean ± SD is presented in the table.

Participant	Familiarization (N)	Experimental (N) *
1	2181	2248
2	1201	1660
3	1967	2176
4	2293	3120
5	881	905
6	1331	1741
7	822	810
8	505	514
9	2828	3205
Mean ± SD	1556 ± 790	1820 ± 969

5.1 Power output

The results from the current study demonstrates that there was no significant improvement on power output (W) after two sets of five seconds maximal isometric CC prior three sets of LSJ between the CON and EXP session (p> 0.05) (Figure 3). However, the results show a greater difference in some individuals when comparing CON versus EXP session (Figure 3).

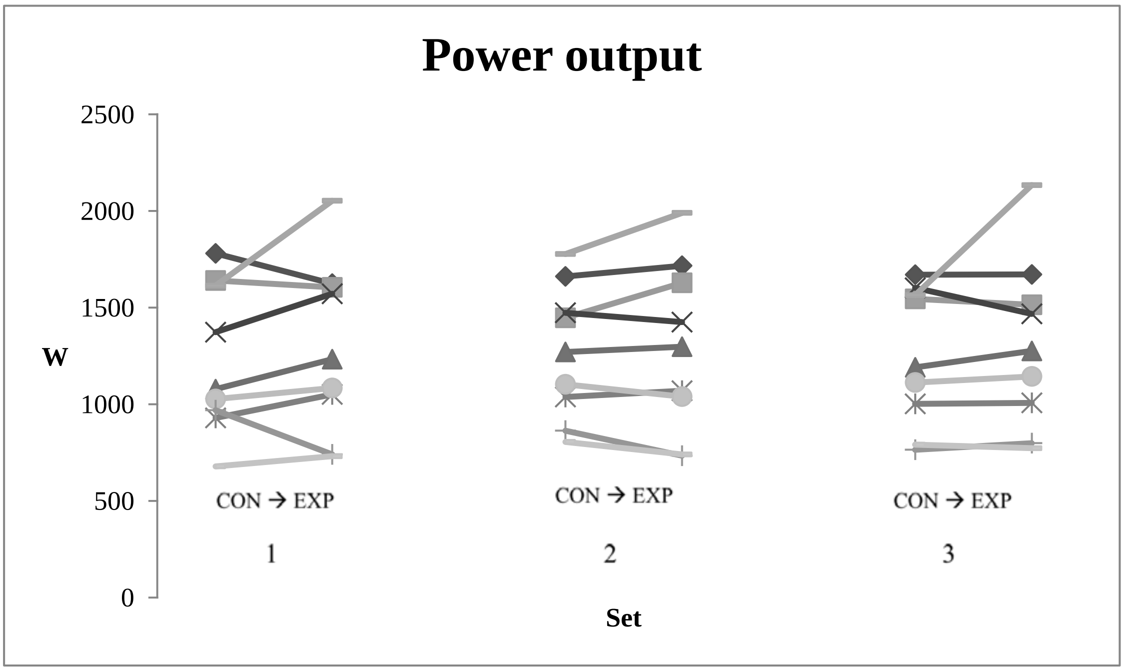

Figure 3. The best mean power output (W) produced at each set and session respectively. No significant difference between each session and set comparing the control (CON) and the experimental (EXP) session ($p > 0.05$). Some participants showed a greater difference on individual basis compared to others between the CON and EXP session. Each participant best mean result at both the CON and EXP session at each set are presented in the table.

5.2 Force production

The study demonstrated no significant improvement on force (N) production after two sets of five seconds maximal isometric maximal isometric CC prior three sets of LSJ, between the CON and EXP session ($p > 0.05$) (Figure 4). However, the results show a greater difference in some individuals when comparing CON versus EXP session (Figure 4).

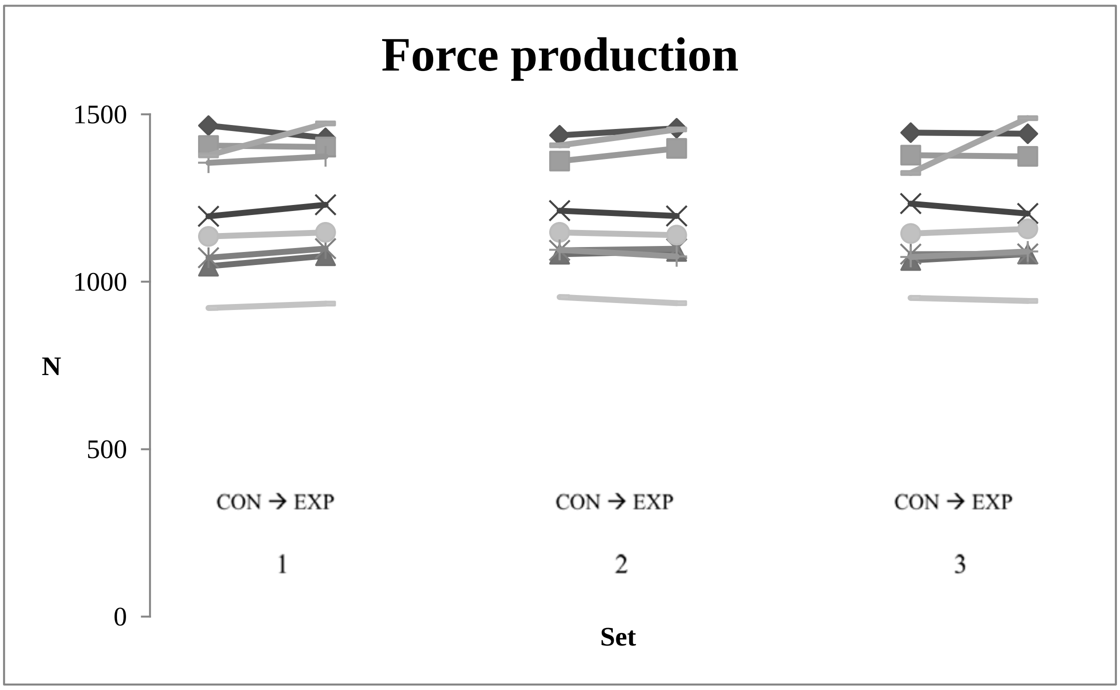

Figure 4. The best mean force (N) produced at each set and session respectively. No significant difference between each session and set comparing the control (CON) and the experimental (EXP) session ($p > 0.05$). Some participants showed a bigger difference on individual basis compared to others between the CON and EXP session. Each participant best mean result at both the CON and EXP session at each set are presented in the table.

5.3 Jump height

The study demonstrated no significant improvement on jump height (cm) after two sets of five seconds maximal isometric CC prior three sets of LSJ, between the CON and EXP session ($p > 0.05$) (Figure 5). However, the results show a greater difference in some individuals over others when comparing CON versus EXP session (Figure 5)

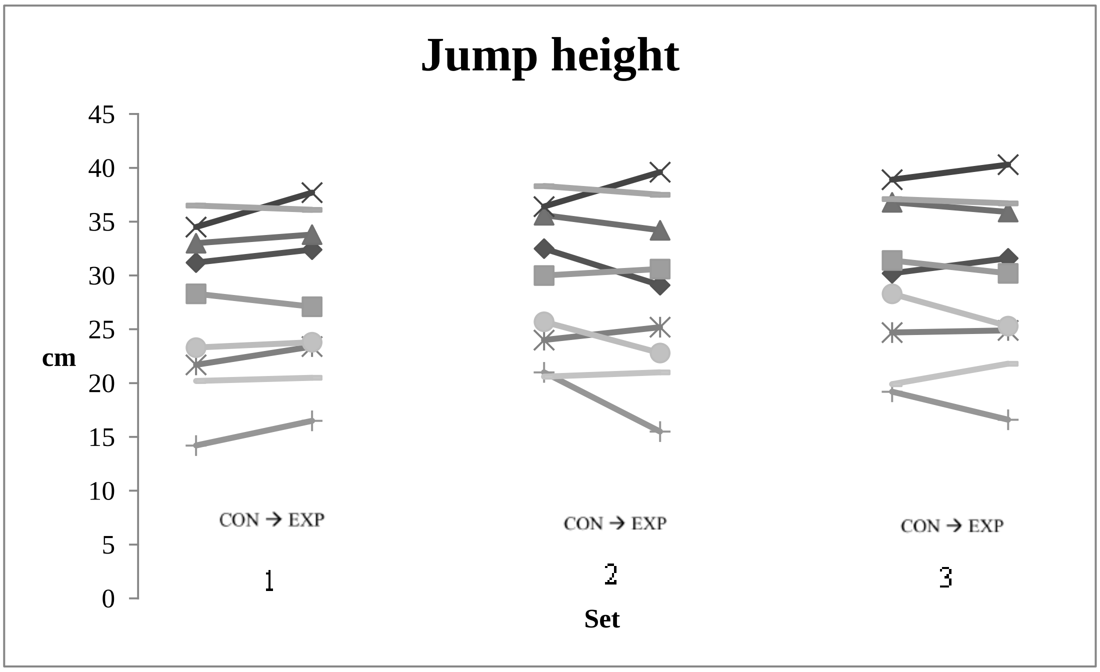

Figure 5. The best mean jump height (cm) at each set and session respectively. No significant difference between each session and set comparing the control (CON) and the experimental (EXP) session ($p > 0.05$). Some participants showed a bigger difference on individual basis compared to others between the CON and EXP session. Each participant best mean result at both the CON and EXP session at each set are presented in the table.

5.4 Velocity

The study demonstrated no significant improvement on velocity (m/s) after two sets of five seconds maximal isometric CC prior three sets of LSJ, between the CON and EXP session ($p > 0.05$) (Figure 6). However, the results show a greater difference in some individuals over other comparing CON versus EXP session (Figure 6).

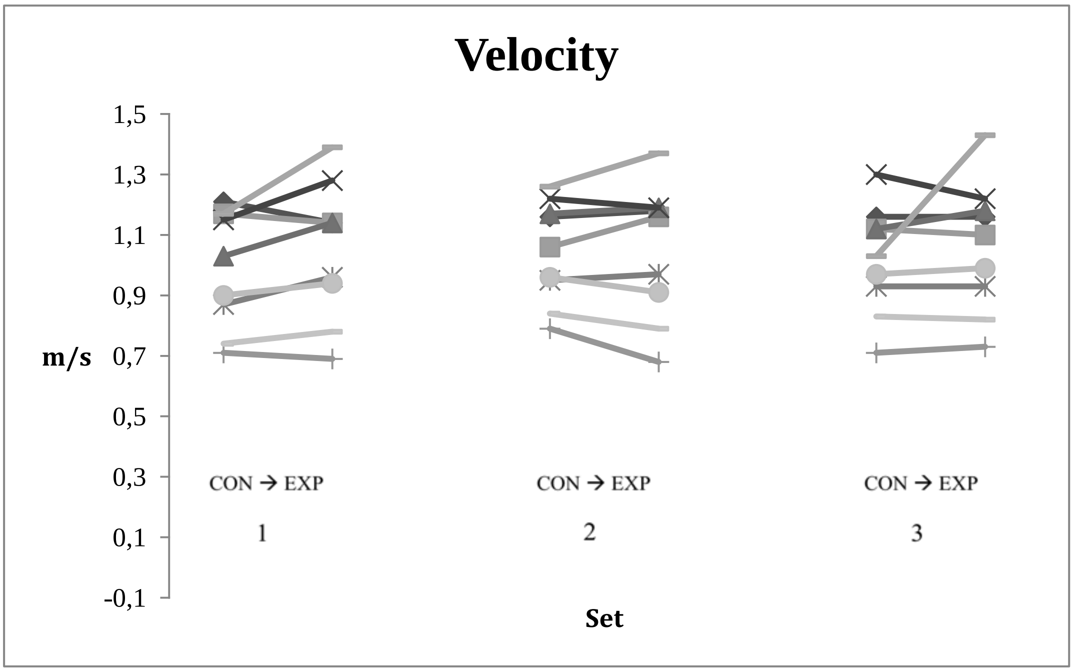

Figure 6. The best mean velocity (m/s) at each set and session respectively. No significant difference between each session and set comparing the control (CON) and the experimental (EXP) session ($p > 0.05$). Some participants showed a bigger difference on individual basis compared to others between the CON and EXP session. Each participant best mean result at both the CON and EXP session at each set are presented in the table.

6 Discussion

The purpose of this study was to investigate if a maximal isometric CC enhances the ability to perform three sets of LSJ. The main findings from the current study indicate that an isometric CC involving two sets of five seconds maximal voluntary isometric contraction has no significant changes on performing three sets of LSJ.

Previous research has demonstrated that a dynamic CC will enhance the explosive strength (McBride, 2005; Clark, 2006; Rahimi, 2007; Yeter & Moir, 2008; Linder, Prins, Mutlata, Derenne, Morgan & Solomon, 2010); in addition, isometric CC protocols have also shown improvements on explosive strength (Rixon et al. 2007; Esformes et al. 2011; Feros et al. 2012).

McBride and Rahimi demonstrated that a series of heavy-loads (> 80% 1RM) prior to explosive movement enhanced the performance, a result supported by several other independent studies. Two studies using isometric CC were Esformes et al. (2011) and Feros et al. (2012) which used one set of seven seconds maximal isometric CC (Esformes et al. 2011) and five sets of five seconds isometric CC (Feros et al. 2012). In the current study the method consisted of two sets of five seconds maximal isometric CC and is similar to what used by Esformes et al. (2011); therefore, we hypothesized that two sets of five seconds isometric conditoning contraction should have been sufficent, which proved not to be the case. In future studies it would be interesting to extend the contraction time (> five seconds) and/or include additional sets (> two sets).

Another important factor that might have played a roll in explaining the lack of a significant effect in this study was perhaps because of each participants strength training background or their strength level. According to previous research the benefits of a CC is greater in participants who demonstrate a greater absolute strength and have a longer strength training background (Young, 1998; Dutchie, 2002; Gourgoulis, 2003; Rixon et al. 2007; Esformes et al. 2011). For example, Esformes et al. (2011) used ten competive rugby players who were familiar with high resistance training and had several years of strength training experience compared to the range of strength training experience of the participants in the present study. Therefore Esformes participants were probably more suited to benefit from the CC.

The total amount of work that was used in the CC, two sets of five seconds maximal voluntary isometric contraction, was perhaps too long for the population used in the present study which mean that they perhaps experienced a fatigue stage. Even if Feros et al. (2012) presented that five sets of five second isometric CC enhanced the rowing performance, the difference between the current study and Feros et al. (2012) was that the population in the Feros study was considerably more trained individuals comparing to that was used in the present study. Even here the physiology of the population tested is perhaps essential to achieve the observed effect; consequently, the benefits of CC training may only be applicable to elite athletes with extensive strength training experience. Perhaps elite athletes have a better neuronal capacity to recruit more muscle fibers, but more research is needed.

No significant changes was found for any of the three LSJ sets performed in the EXP session. Previous research has reported that the optimal recovery period after a CC has a range between 1 – 18 minutes (Young, Jenner & Griffiths, 1998; Dutchie, Young & Aitken, 2002; Chiu et al. 2003; Gourgoulis et al. 2003; Hilfiker, Hubner, Lorenz & Marti, 2007; Brandenburg, 2005; Bevan et al 2010; Macintosh, Robillard, & Tomaras, 2012; Wilson et al. 2012). In the present study the first set of LSJ was performed two minutes after the CC and the following LSJ sets was performed at four and six minute after the CC. Based on previous research an extended rest period between the CC and first LSJ (> 2 min) would probably contribute to significant changes in the LSJ. Our findings suggest that rest periods of two minutes or less are insufficient to enhance the performance on the LSJ, possibly because the positive effects of PAPs did not overcome the negative effects of muscle fatigue. However, no significant decrease was found on the following two sets of LSJ. The population used in the study was physically active individuals with different types of sports/athletic backgrounds were some participants showed a greater increase then others which might indicate that these individuals are used to performing explosive exercises or have a greater amount of type 2 fibers. This hypothesis is supported by previous mentioned research. Kilduff et al. (2007) demonstrated a significant improvement after eight minutes on 23 elite rugby players. Another study written by Okuno et al. (2013) presented a significant improvement on RSA after four minutes on 15 elite handball players. Lima et al. (2011) presented also a significant improvement on CMJ and 50 m sprint after five minutes on elite sprinters. Considering the fact that the rest period proved to be too short and the first LSJ was performed too soon after the CC, the physiological mechanisms that support a PAP effect may have been insufficiently activated. Additionally, it is unlikely that the CC protocol induced enough muscle fatigue to mask the PAP effects. If this is the case a significant reduction in the second or third LSJ set should have been found. This hypothesis is supported by what Batista et al. (2011) who reported a variance of the response on individual basis after the CC.

We suggest that the CC chosen to induce PAP should be the closest to the actual performance task so the neural drive would travel through same pathways during both the CC and the performance. In support of this, a number of studies have found significant improvements on CMJ performance after completing dynamic or isometric squats (Gourgoulis et al. 2003; Weber et al. 2008). In line with previous studies the CC in the present study was performed as an isometric squat and therefore the neural drive should mirror that used in the performance task (LSJ), despite this the results of the present study found no significant improvement. An isometric CC is unlikely to benefit non-elite athletes possibly due to the facts that the benefits can only be obtained in individuals with long histories of strength training and that rest periods shorter than two minutes are insufficient to either: a) activate the biochemical/physiological events necessary for PAP or b) for the PAP to overcome muscle fatigue. Therefore, the lack of significance is more likely explained by the study design.

According to the findings and from the present study, it is perhaps more suitable to perform this type of research on larger study group, even if a larger study group would not have change the results, it's still better to perform research on a larger group. Another important factor is to also assess each participants absolute strength and strength training experience to reduce confounding elements such as data spread due to variability of each participants absolute strength.

6.1 Methodological considerations

Another reason why no significant results were found in the present study was perhaps because of the study design. The performance task (LSJ) was more difficult for some participants even if a FAM session was performed and the LSJ was executed in a barbell suspended in a Smith-machine (Cybex), but some participants had never before performed a similar exercise. Several studies have used CMJ or
JS as an evaluating method and presented significant improved results (Stone et al. 2004; Clark et al. 2006; Ronnestad, Kvamme, Sunde & Raastad, 2008; Weber et al. 2008). The exercise LSJ was chosen because there are few studies which have used it as an assessment method. We wanted to examine if it was possible to achieve similar results as previous research have found by using CMJ and JS which are quite similar to LSJ and therefore LSJ was chosen. The results found no significant changes when using LSJ, perhaps because some participants had difficulties with the performing the exercise. Therefore we suggest that exercises such as CMJ or JS should be used which are easier to perform with the lack of external resistance. CMJ and JS are also more similar too explosive sports e.g. basketball, high jump and sport involving sprint and jumping were no external resistance is used.

Another hypothesis why no significant changes were found might be because of the resistance weight. The lightest participant was 48 kg and the heaviest was 92 kg. The resistance weight was 40 kg and for a person that weighs 48 kg it's equal to a percentage at 83 % of body weight, and for the 92 kg person it was 43 % of body weight. Therefore it might be difficult for a light weighted person to achieve its highest potential and if this is a reason why, the resistance should have been at 50 % of body weight, which is a more relevant resistance. However, the results were not compared between each individual, it was compared for each individual and therefore the resistance used should perhaps not have the biggest influence on the effects of PAP. If further research using a Loaded Squat Jumps as a performance task, they should consider using a resistance at a certain percentage of body weight or 1RM which is more accurate and more relative to the participants strength level.

In the current study we used three sets of LSJ and each was performed at different time intervals (two, four and six minutes) post a CC in the EXP session, and after a total rest period of six minutes in the CON session. The results showed an individual response after each time interval, which suggests that each participant benefits differently. Therefore, we hypothesis that some participants increased or decreased the physical effect after performing either the first or the second set of LSJ. The PAP response might have been different if each time interval was completed on different days (i.e. one session with two minute rest, one with four minute and one with six minute post CC) and in additional regarding the time interval, the rest period at each session were perhaps not equal. In the CON session a total of six minutes was adopted between the warm-up and the first set of LSJ, and in EXP a four-minute rest was adopted before the CC followed by an additional two-minute rest (4 + 2 = 6). The study design used in the present study was based on what previous researchers have used as designs (Rahimi et al. 2007; Feros et al 2012). No measurement was used to investigate whether the rest period was equal between each session. Assume there was a difference on the rest period between each session it might have affected the response of the CC and probably influence the results on the physical parameters when performing the three sets of LSJ.

We cannot suggest that a reason why no significant was found, was because of the ISO_{max} performed at the EXP. Each participant did perform at least their maximal voluntary isometric contraction (ISO_{max}) at the EXP session, because a significant improvement was found between ISO_{max}-FAM and the ISO_{max}-EXP. Despite the fact that there was an increase on ISO_{max}, it’s a possibility that a learning effect had been adopted when the participants performed the ISO_{max}-EXP and therefore the spread of data. Participants 2, 4, 6 and 9 had an increase of 20 % on ISO_{max} between the FAM and EXP session. If this large increase was because of a learning effect, there’s a possibility that a learning effect was also adopted on the LSJ attempts was adopted between the CON and EXP session. Even if a FAM session was executed and each participant becomes familiar with the exercise, it was perhaps insufficient to minimize the learning effect on the LSJs. To be able to minimize the learning effect another session should have been executed in the present study to investigate if the learning effect could have been minimized.

6.2 Conclusion

In conclusion, this study evaluated the effect of performing an isometric CC prior to three sets of LSJ. The main findings suggest that an isometric CC consisting of two sets of five seconds maximal voluntary contraction is not enough to enhance the performance on LSJ in non-elite active individuals. We believe that more research needs to be done with different kinds of populations, rest periods and different CCs. Further investigation should also consider performing a study design, which involves a test re-test to determine if the response is the similar at or if there is a variance.

7 Practical applications

Based on the main findings of this study, inducing an isometric CC of two sets of five seconds in a warm-up routine will not improve the ability to produce explosive force in physically active individuals. If it is possible to enhance the performance by CC still remains inconclusive and the various factors that play a role in how well an individual can take advantage of a CC. If a CC has the ability to achieve a PAP effect, the improvements might be small and therefore the benefits is perhaps more suitable to elite active individuals, because of the fact that it might reach her or his maximal possible performance. We also suggest that it is important for coaches and leaders to find their own way to utilize the potential benefits.

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10 Appendix

10.1 Informed consent

Samtycke vid deltagande

Deltagare: ____

Född: ____-_____-________ (dd/mm/yyyy)

Telefonnummer:____

Jag har blivit rekryterad till forskningsprojektet ”*Changes in Loaded Squat Jump performance following a series of isometric conditioning contraction*” Jag garanterar att efter ha läst skriftlig information och diskuterat med ansvarig forskare samtycker jag om mitt deltagande, helt frivilligt och utan påtryckning, i detta forskningsprojekt. Jag är medveten om att jag kan återkalla mitt samtycke och därmed avbryta mitt deltagande i forskningsprojektet.

Syftet med studien är att undersöka om ett nytt inslag i uppvärmningen kan bidra till en ökad effekt vid explosiva moment. Studien kommer att bestå av tre olika tillfällen under loppet av 2-3 dagar. Jag samtycker att jag har förstått syftet med studien och vad respektive testtillfälle innebär.

Jag är medveten om de fysiska mätningarna och jag har förstått innebörden och riskerna med dessa. Jag är även medveten om att forskningsprojektet kan ge mig t.ex. träningsvärk och trötthetskänsla av testningen.

Jag är medveten om att mina personuppgifter hanteras konfidentiellt och att det inte är möjligt att identifieras i forskningsrapporten. Jag garanterar att jag är frisk. Jag är medveten om att syftet med informationen som är delgiven av ansvarig forskare är för att säkerställa säkerhet, och att jag skall följa alla instruktioner. Jag godkänner att ansvarig forskare får avbryta mitt deltagande.

______________________________/ /2013_____________________________

Ort och datum underskrift

10.2 Literature search

Aim and research questions:

The aim of this study was to investigate the effects of performing an isometric conditioning contraction in physical active individuals prior CC prior three sets of LSJ. Specific research questions were:

- Will a CC involving two sets of five seconds maximal voluntary isometric contractions improve performance in a LSJ?

Words used in the literature search

Postactivation potentiation *Conditioning Contraction* *Countermovement jump* *Isometric contraction* *Heavy – loads exercise* *Explosive strength* *Strength training* *Vertical jump* *Squat Jump* *Warm – up*

Databases used

GIH:s bibliotekskatalog *PubMed* *Ebsco* *Google Scholar*

Relevant search strings

Pubmed – Postactivation potentiation
Pubmed – Conditioning Contraction
Ebsco – Heavy loads
Ebsco – Heavy-loads exercise

Commentary

The databases at GIH were very useful because GIH are subscribers of electronic journals and therefore it was very easy to find full text PDFs.