

Effects of Different Warm-up Protocols on Leg Press One Repetition Maximum Performance

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Abstract

In order to investigate the effects of different warm-up protocols on one repetition maximum (1RM) leg press performance, 23 rowers (age 21.48 ± 3.12 years, height 185.17 ± 8.22 cm, body mass 83.86 ± 8.7 kg.) completed 1RM leg press tests after four different general warm-up conditions with a standardized specific warm-up. The workloads of the warm-up protocols were individually designed according to the results of the incremental maximal rowing ergometer test that applied initially. The duration of the protocols were fixed as 15 minutes (min.) for each participant, but there were differences in the intensity of the warm-up. In statistical analysis, warm-up conditions were set as fixed factor while participants as a random factor. Tukey post hoc test was employed whenever a significant difference was found. A probability level of 0.05 was established to determine statistical significance. All statistical analyses were conducted using SPSS version 20.

As a conclusion, approximately 4% higher 1 RM results were obtained after low intensity (40% of VO_{2Max}) protocols which contain two intermittent sprints that last 15 seconds in the last 5 min. of the protocol. Thus, the results of the present study are important for both practical and research environments.

Keywords: strength, performance, ergometer, resistance, leg press, warm-up

Introduction

Strength is one of the most important predictors of the performance in body-weight supported sports such as rowing and canoe-kayak (Akca and Muniroglu, 2008; Gee et al., 2011; McKean and Burkett, 2014). Because of the demonstrated relationships between strength measures and rowing performance, strength training appears to be an essential part of the training programs of rowers (Gee et al., 2011; McNeely et al., 2005). Testing of one repetition maximum (1RM) and designing the training plan according to the test results are an essential part of an athletic preparation (Baechle and Earle, 2008). 1RM test is the most common measure to assess the strength level of an athlete and the accuracy of this test is crucial to determine individual training loads precisely (Brown and Weir, 2001). High-reliability values were reported (intra-class correlations between 0.82-0.99) for maximal strength tests involving leg pressing and arm pulling in rowers (Lawton et al., 2011a). Dynamic lower body strength tests that determined the maximal external load for a 1RM leg press (kg), isokinetic leg extension peak force (N) or leg press peak power (W) proved to be associated with 2000-m ergometer times ($r = -0.54$ to -0.68 ; $p < 0.05$). (Lawton et al., 2011b; Lawton et al., 2012; Lawton et al., 2013)

The warm-up procedure (type of the exercise, stretching, specific activity) is among the factors that affect the precision of the 1RM strength tests (Bishop, 2003a; Bishop, 2003b; Brown and Weir, 2001; Woods et al., 2007). It is generally recommended that the warm-up before maximum strength testing should contain both general aerobic and specific (task related, mimicking) exercises (Bishop, 2003b; Brown and Weir, 2001; Pescatello, 2014). The main aim of the general warm-up exercises is to increase body temperature, whereas the specific warm-up targets to increase neuromuscular activation (Bishop, 2003b; Brown and Weir, 2001; Gourgoulis et al., 2003; Pescatello, 2014). Recent studies demonstrated the beneficial effects of longer (15 min) duration general warm-ups over a shorter duration (5-10 min) on 1 RM strength performance (Barroso et al., 2013; Stewart et al., 2003). Besides, in a study that conducted on a state level sprint kayakers, significantly better 500-m kayak ergometer performances were demonstrated after the warm-up that includes short (10 seconds) supramaximal (200% of VO_{2Max}) intervals compared with continuous, constant load warm-up (Bishop et al., 2003). One of the aims of the present study is to investigate whether the addition of intermittent high force movements into a warm-up improves 1RM strength performance.

Leg press is selected to study in this research because it is one of the most common exercises to develop lower body strength and frequently used in the training programs of rowers, besides significant relationships between 1RM leg press scores and rowing performance were demonstrated in previous studies (Akca, 2014; Chun-Jung et al., 2007; Yoshiga and Higuchi, 2003).

The purpose of this study was to compare the effects of different general warm-up protocols on leg press 1 RM performance.

Materials and Methods

To demonstrate the effectiveness of different general warm-up protocols on leg press 1RM performance, subjects were tested in four different conditions. Initially, subjects performed 2000-m time trial and maximal incremental exercise test on rowing ergometer in order to determine the power values that used for the warm-up protocols.

In a randomized crossover fashion, 1RM leg press performance was measured in four different occasions. Different general warm-up protocols were used for each occasion. After general warm-up, subjects were instructed to rest for 3 minutes and performed the specific warm-up protocol that standardized for all conditions. HR, RPE, and Lactate were measured before and immediately after each warm-up session.

Subjects were asked to refrain from caffeine, alcohol and strenuous exercise for 48 hours before tests. Besides, subjects were instructed to keep a diary of dietary intake on the day before tests and the same dietary intake was replicated in the following tests. Tests were conducted at least 48 hours apart and approximately at the same time of the day (± 1 hr) for each subject.

1RM strength scores would be expected to be at its highest during the specific training period and can be reduced because of the altered training focus during the competitive period (García-Pallarés et al., 2009). The tests were conducted at the end of the general preparation period of the yearly training plan.

Subjects

Twenty-three male collegiate rowers (age 21.48 ± 3.12 years, height 185.17 ± 8.22 cm, body mass 83.86 ± 8.7 kg, mean 2000 m. time = 394.4 ± 11.5 seconds) volunteered to participate in this study. All subjects were trained, experienced and performed on the model of ergometer used for the measurements and they also have at least 34 months of strength training experience (40.4 ± 5.8 months) and performed leg press exercise during their regular training routine at least twice a week. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and approved by the institutional human research ethics committee. After reading a sheet that contained information with regard to the study design and any possible risks, all subjects signed an informed consent form.

Procedures

2000 m. Time Trial Test

An air-braked rowing ergometer (model D, Concept II, Morrisville, VT, USA) was used for rowing performance measures. Drag factor setting of the ergometers was adjusted to 140 as recommended by Amateur Rowing Association (ARA) for heavyweight men rowers (O'Neill and Skelton, 2004). For the time trial test, subjects were asked to perform an all-out 2000-m. on ergometer. Heart rate (HR) was recorded with a telemetric HR monitor throughout the test (s610i, Polar Electro Oy, Finland). Completion time, stroke rate, HR and average power outputs were recorded immediately after the test for the whole test and every 500 m splits separately.

Incremental Exercise Test

To determine the metabolic responses to loading, incremental rowing ergometer test recommended by Australian Institute of Sport (AIS) was executed (Hahn A et al., 2000). The test protocol was discontinuous with progressive 4 min increments, consisting of six submaximal stages and a final (7th) maximal stage. Each stage was separated by one-minute recovery interval during which blood samples for lactate analyses were taken from earlobe. The workloads for the submaximal stages were determined individually based on each subject's best time during 2000 m. time trial test. The average 500 meters pace of the 2000 meters maximal test time plus four seconds was calculated, to give the pace (per 500 m) that the subject was required to maintain during the sixth stage of the test. Successive amounts of 6 seconds per 500 m were added in order to calculate the required pace for the earlier

workloads. The final (7th) stage performed with 4 min. maximal effort. Verbal encouragement was given in the final stage of the test.

Gas exchange during the test was measured breath by breath with a gas analysis system (Oxycon Mobile, Jaeger GmbH, Germany). HR was recorded during test via the sensor of gas analyser using T-31 coded transmitter belt (Polar Electro OY, Finland). Blood lactate concentrations were measured using an automated lactate analyser (YSI Sport 1500, Yellow Springs, Ohio, USA). The rating of perceived exertion (RPE) was assessed before and after each stage (Borg, 1982). Lactate and gas analysers were calibrated prior to tests according to manufacturer's instructions. VO_2 values were averaged over 15-second intervals and VO_{2Max} was determined by averaging the four highest consecutive oxygen consumption value recorded during the last stage of the test.

Familiarization 1 RM Leg Press Sessions

Subjects performed a familiarization session before undertaking any of the warm-up protocols in order to optimize the effectiveness of the specific warm-up and testing application. The individual settings of the leg press machine (Diesel Fitness, Florida, USA) were recorded during the familiarization session and replicated during the 1 RM test. Subjects performed self-selected warm-up for 5 min before the session (Barroso et al., 2013).

Warm-Up Protocols

The protocols were performed on the same ergometer used for the maximal incremental exercise test. Beneficial effects of longer (15 min) duration general warm-ups over shorter duration (5-10 min) on 1RM performance have been demonstrated (Barroso et al., 2013; Stewart et al., 2003). Therefore, 15 min was chosen as the duration of each protocol. Even though the duration of each warm-up protocol was the same, there were differences in the intensity of each condition. The combinations were as follows:

1. Constant Low Intensity (CLI): 15 min at the power output that corresponded to 40% of VO_{2Max} .
2. Low-Frequency Intermittent (LFI): 13 min at the power output that corresponded to 40% of VO_{2Max} and two 15 seconds sprints with the intensity equivalent to 170% of the power output at VO_{2Max} during the last 2 min, each separated by 45 seconds of recovery at 40% of VO_{2Max} .
3. Moderate Frequency Intermittent (MFI): 10 min at the power output that corresponded to 40% of VO_{2Max} and five 15 seconds sprints with the intensity equivalent to 170% of the power output at VO_{2Max} during the last 5 min, each separated by 45 seconds of recovery at 40% of VO_{2Max} .
4. High-Frequency Intermittent (HFI): 5 min at the power output that corresponded to 40% of VO_{2Max} and ten times 15 seconds sprints with the intensity equivalent to 170% of the power output at VO_{2Max} during the beginning of every min. in the last 10 min.

Subjects were only allowed to perform light short-duration submaximal stretching exercises during the warm-up because the negative effects of extensive stretching exercises on strength performance were demonstrated in various studies (Bacurau et al., 2009; Costa et al., 2014; Rubini et al., 2007).

1RM Leg Press Test

After completion of each warm-up protocol, subjects were instructed to rest for three min. After the rest, subjects performed the same specific warm-up regardless of their general

warm-up protocol. The specific warm-up consisted, one set of eight repetitions and one set of three repetitions of leg press at 50% and 70% of the familiarization session leg press performances respectively with 2 min. rest interval. Three min. of rest was given after the specific warm-up and subjects had five attempts to achieve the 1RM score. The relief interval between the attempts was three min (Akca, 2014; Barroso et al., 2013).

Subjects started the test with the knees fully extended and feet were on the footings. Subjects were asked to flex their knees to 90 degrees at the end of the eccentric phase before extension (concentric phase) (Brown and Weir, 2001). A certified strength coach was supervised tests to provide correct movement technique.

Data Analysis

Normality of the distribution was analyzed using Shapiro-Wilk test. Lactate, HR and RPE values from each warm-up protocol were compared using a mixed model analysis. Warm-up conditions were set as fixed factor with subjects as a random factor. Tukey post hoc test was employed whenever a significant difference was found. A probability level of 0.05 was established to determine statistical significance. All statistical analyses were conducted using SPSS version 20 (SPSS Inc., Chicago, IL).

Results

Mean maximal oxygen consumption of the subjects was found as 58.1 ± 4.2 ml.kg.min⁻¹. Lactate, HR and RPE values were not significantly different at rest between warm-up protocol groups ($p=0.994$).

Table 1. Values of the measured variables after each warm-up protocol

Warm-up Protocol	RPE	HR (b.min ⁻¹)	Lactate (mmol.L ⁻¹)
CLI	10.8 ± 1.9#	119.3 ± 13.4#	1.1 ± 0.3#
LFI	12.6 ± 2.3‡	131.3 ± 12.2‡	1.8 ± 0.5‡
MFI	13.6 ± 2.2‡	140.8 ± 14.1‡	2.2 ± 0.4‡
HFI	16.1 ± 3.3#	166.6 ± 16.7#	3.3 ± 0.6#

HR = heart rate; RPE = Rating of perceived exertion; CLI = Constant low intensity; LFI= Low frequency intermittent; MFI = Moderate frequency intermittent; HFI = High frequency intermittent

Significantly different ($p < 0.05$) from all other protocols.

‡ Significantly different ($p < 0.05$) from CLI and HFI.

As presented in Table 1; differences in HR, RPE, and Lactate parameters were statistically significant after HFI protocol compared with any other protocol ($p=0.003$). Lactate values were significantly different between CLI and HFI and other protocols ($p=0.002$). The differences of the values obtained following LFI and MFI protocols were not significant ($p>0.05$).

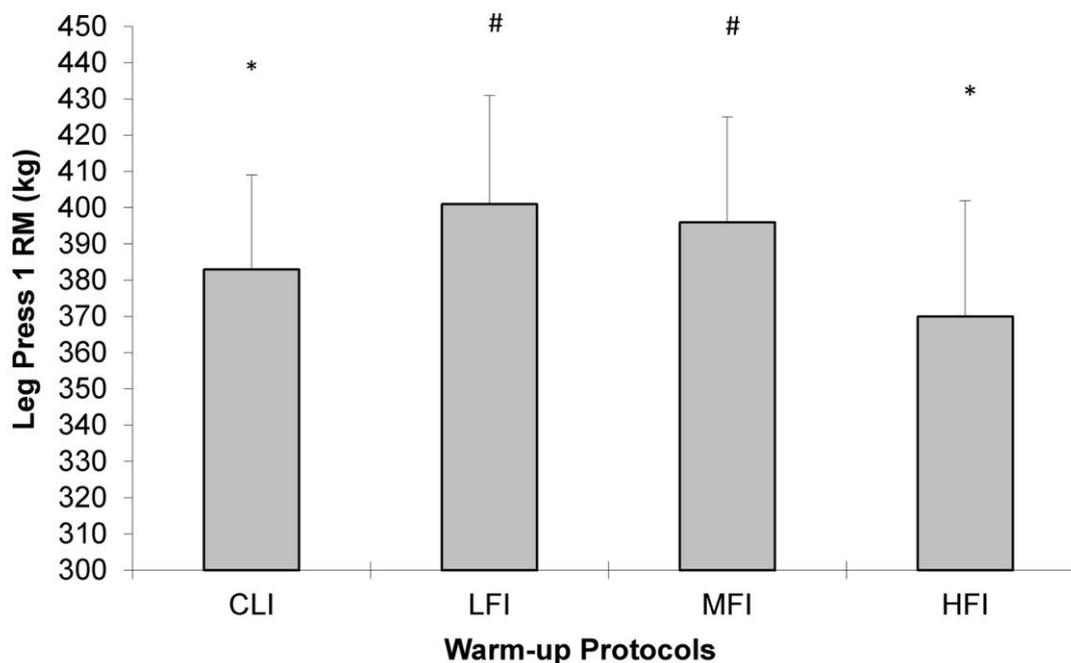


Figure 1. Leg Press 1RM scores for each warm-up protocol.

CLI= Constant low intensity; LFI= Low frequency intermittent; MFI= Moderate frequency intermittent; HFI= High frequency intermittent; * Significantly different ($p < 0.05$) from other protocols; # Significantly different ($p < 0.05$) from CLI and HFI.

As presented in Figure 1; 1RM leg press performance was higher after LFI and MFI protocols compared with others ($p = 0.002$). On the contrary, 1RM values were significantly lower when using HFI warm-up protocol ($p = 0.001$). There is a significant difference between the scores of HFI and CLI protocols ($p = 0.003$). No differences were detected between LFI and MFI protocols ($p > 0.05$).

Discussion

The importance of leg strength on rowing performance has been demonstrated in several studies (Baechle and Earle, 2008; Chun-Jung et al., 2007; Gee et al., 2011; Lawton et al., 2011a; McNeely et al., 2005). Strength can be considered as one of the limiting factors of rowing performance along with the various other factors such as starting power and muscular endurance (Gee et al., 2011). Thus, determining the leg press 1RM performance precisely as possible is crucial to optimize the individual training plan of each rower.

According to the results of the present study, 1RM leg press performance was found significantly higher after LFI and MFI warm-up protocols compared with CLI and HFI protocols and the 1RM performance was significantly lower after HFI warm-up protocol than any other protocol. The 1RM scores were higher after LFI warm-up protocol compared with MFI but differences were not significant.

The results of the present study indicated that HR and RPE values determined after HFI warm-up were approximately 30% higher than those after CLI, LFI and MFI protocols (Table 1). The physiological stress that associated with the workload of HFI warm-up protocol seems to lead to muscle fatigue, which may explain the decrease in 1RM performance (Barroso et al., 2013; Bishop, 2003b). Importance of increasing the body temperature before a short-term activity like 1RM test has been established by Bishop (2003b) and by increasing body temperature appropriately, harmful effects of excess fatigue can be avoided.

5-10 min. duration warm-up was recommended by testing guidelines before strength testing (Baechle and Earle, 2008; Pescatello, 2014). However, aforementioned guidelines have little scientific support and suggested warm-up durations seem to be shorter than necessary to induce performance enhancement in strength tests. Several studies demonstrated that a significant increase in muscle temperature has occurred only after 15-20 min. of aerobic activity (Price and Campbell, 1997; Stewart et al., 2003). Better performance for 1RM Leg press was demonstrated while using 15 min. duration warm-up compared with 10 min (Barroso et al., 2013). 15 min. was selected as the duration of each warm-up conditions in the current study according to the latest literature.

Intensity of the warm-up is an important determinant, which affects the test result and should be organized carefully. According to the results of the current study, combining warm-up with long duration (15 min) and high frequency of supramaximal intermittent sprints (10 sprints) may impair 1RM leg press performance because of the accumulated effect of muscle fatigue. In the light of the recent findings, it is conceivable to say that the warm-up protocol that lasts 15 min. should be combined with low ($\leq 40\%$ of VO_{2Max}) exercise intensities with two to five supramaximal (about 170% of VO_{2Max} workload) sprints that last 15 seconds to avoid fatigue development and to employ lower body 1RM strength testing with optimum precision.

In the current study, the LFI warm-up protocol produced better results compared to other protocols. Furthermore, for LFI protocol, physiological stress parameters (HR, RPE, and Lactate) were the second lowest among four protocols. Although CLI induced lower physiological stress than LFI, it can be speculated that because of the lack of the intermittent high-intensity efforts in the CLI protocol, exercise impulse was insufficient to trigger appropriate muscle temperature and 1RM performance was lower compared with LFI.

The strength performance difference after using LFI warm-up protocol may be considered small (approx. 4%). However; performance improvements about 4% were reported in bench press 1RM values after a periodized 12-week training cycle in eleven elite male kayakers (Garcia-Pallares et al., 2010). Besides, the improvement about 3-4% is similar to those observed in response to a long-term strength training in strength-trained individuals (Kraemer, 1997).

Strength performance testing allows the trainer to monitor the progression of the on-going training plan. Therefore, it is vital to detect true 1RM value that reflects the maximal possible strength of the athlete. It can be concluded that the warm-up has an important effect on 1RM leg press performance, according to the results of the present study. To obtain the most precise 1RM leg press result, the general warm-up before the test should contain 10 min of low intensity (40% VO_{2Max}) exercise and two supramaximal sprints, which last 15 seconds, must be added at the last 5 min. of the warm-up. Performance improvement about 4% after LFI protocol is similar to a progression of highly trained individuals' strength values over a long-term strength training. Thus, the results of the present study are important for both practical and research environments.

These results must be viewed with caution because only collegiate male rowers were studied. Whether the trend of the 1RM testing results is similar after the similar warm-up protocols in different athletic populations is a good perspective to future research. On the other hand, using rowing ergometer as a warm-up device before 1RM leg press testing can be recommended since rowing ergometers are easy to find and used regularly in most of the gyms. However, if coach or personal trainer decides to use rowing ergometer for warm-up before 1RM leg press test caution must be given to the rowing technique of an individual; because the differences in the application of rowing technique may affect the physiological variables. Practitioners must keep in mind that these suggestions are limited to 1RM lower body maximum strength tests and should not be applied to other strength tests such as strength endurance or power.

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Conflict of Interest

The authors have not declared any conflicts of interest.

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