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The Effect of a High-intensity Functional Training Warm-up on Deadlift One-repetition Maximum Performance

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ABSTRACT

Purpose: To assess a high-intensity functional training (HIFT) workout compared with a traditional general warmup (GWU) on 1-RM performance.
Methods: Participants included 20 (n = 10 females) healthy adults aged 18 to 25 years with experience performing the deadlift. On visit one, participants completed maximal voluntary contractions for the gluteus maximus, vastus lateralis, and biceps femoris muscles using surface electromyography. Visits two and three were randomly counterbalanced into two GWUs: 1) Traditional (TRAD) warm-up - 15 minutes of cycle ergometry exercise at 55-60% of maximum heart rate; 2) HIFT warm-up - 15 minutes to complete as many rounds and reps as possible of row (females: 200 meters, males: 250 meters), 5 burpees, 10 kettlebell swings (females: 35 pounds, males: 50 pounds), and 15 air squats. The variables assessed were 1-RM, force, power, velocity, and muscular activity.
Results: Paired samples t-tests revealed no differences (all $p \geq 0.08$) in 1-RM, force, power, or muscular activity between the TRAD and HIFT conditions. Higher heart rate ($p < 0.001$) and rating of perceived exertion (RPE) ($p < 0.001$) were exhibited immediately after the HIFT warmup compared with the TRAD warmup.
Conclusions: Although intensity was higher immediately after the HIFT warmup, there were no differences in 1-RM performance, force or power output, or muscular activity, after a bout of high-intensity functional training exercise compared with a traditional warmup preceding a 1-RM lift. Performing high-intensity exercise preceding a 1-RM attempt did not impair performance for the conventional barbell deadlift 1-RM.

Keywords: Warmup, High-intensity functional training, one-repetition maximum .

INTRODUCTION

A proper warm-up preceding a bout of resistance exercise is important to ensure optimal performance and to reduce the chance of injury (Coburn & Malek, 2011; Fradkin et al., 2010; Woods et al., 2007).The standard for assessing muscular strength is performing a one-repetition maximum (1-RM) test (Liguori, 2020). Throughout a training macrocycle, it is important to establish a 1-RM to assess baseline strength and monitor progress within a program. A 1-RM requires maximal effort from the target musculature. For this reason, a proper warm-up is crucial to prevent injury and recruit the neuromuscular system to work against resistance safely and effectively (Bishop, 2003; Coburn & Malek, 2011). It is recommended that the most effective resistance training routines include a general warm-up (GWU) to increase muscle core temperature and joint elasticity and a specific warmup (SWU) to engage the neuromuscular system for subsequent recruitment and activation (Abad et al., 2011; Coburn & Malek, 2011; Haff & Triplett, 2021; Liguori, 2020; Ribeiro et al., 2021).

Current SWU guidelines have been established and shown to be effective when considering a subsequent 1-RM lift attempt (Haff & Triplett, 2021). However, the proper protocol for the GWU preceding the SWU for a 1-RM attempt is less clear (Abad et al., 2011; Barnes et al., 2017; Barroso et al., 2013; Gil et al., 2019), which suggests there is a dearth of empirical evidence for the proper warmup protocol preceding a 1-RM test (Ribeiro et al., 2021). For example, current research has used lower body machines (e.g., leg press) and upper body free weight exercises (e.g., bench press) to test the 1-RM. However, these studies used a smaller sample size (i.e., 16 or less) (Abad et al., 2011; Barroso et al., 2013; Firat et al., 2018; Fırat & Dicle, 2018), and lacked multiple sources of measurement, such as velocity and power (Ribeiro et al., 2021). Additionally, these previous studies are limited to a GWU of only a single modality aerobic activity, such as the cycle or rower ergometer and light stretching exercises (Abad et al., 2011; Barroso et al., 2013; Firat et al., 2018; Fırat & Dicle, 2018). The potential problem here is only one modality of exercise is performed and when utilizing the cycle ergometer, which only augments blood flow to the lower extremities and not the entire body (Calbet et al., 2007; Joyner & Casey, 2015). Furthermore, performing warm-ups on the cycle ergometer may not increase adrenaline and testosterone release as much as other, full body movements since sitting releases lower catecholamine concentrations than when in an upright position (Zouhal et al., 2008).

Most previous studies report an inverse relationship with strength performance and warm-up intensity after about 70% VO^2_{max} (Barroso et al., 2013; Bishop, 2003). However, high-intensity exercise has demonstrated to release greater epinephrine and norepinephrine than low- and moderate-intensity exercise (Zouhal et al., 2008). Because there is a positive relationship between strength and adrenaline release (Galbo, 1986; Kraemer et al., 1987), this topic of research deserves further attention. Moreover, two studies have suggested performing short bouts of high-intensity efforts towards the end of a 15-minute warm-up improves 1-RM performance (Firat et al., 2018; Fırat & Dicle, 2018). In addition, a single study concluded that a warm-up of maximal strength may elicit higher force production for the upper and lower limbs (Luz Junior et al., 2014) and a review of upper body warm-ups found high-load dynamic warm-ups to have positive effects on strength and power, whereas low-load dynamic warm-ups had no effect (McCrary et al., 2015). Together, these four investigations point to how using high-intensity and resistance exercise in the warm-up may lead to greater force production.
To continue exploring the effects of different warmups on 1-RM performance, testing a novel GWU that includes full body movements, higher-intensity, and moderate duration (15 minutes) preceding the SWU is warranted. A protocol such as this is described as high-intensity functional training (HIFT) (Feito et al., 2018). HIFT is a relatively new modality of fitness training that involves performing functional, multi-muscle group movements at a relatively high intensity for greater muscle activation than more traditional exercise (Feito et al., 2018). It is proposed that a warm-up composed of HIFT could provide a better physiological and neural stimulus than a traditional warm-up.

Therefore, the purpose of this study was to investigate the effect of a novel HIFT GWU on 1-RM performance, force and power output, and neuromuscular activity on the barbell conventional deadlift exercise. The hypotheses were there would be no differences in 1-RM, force, power output, or neuromuscular activity between the warmup conditions.

METHODS

Participants

The participants for the current study were recruited by e-mail, fliers posted, and word of mouth. For this investigation, 20 (n = 10 males, 10 females) participants between the ages of 18 to 25 were recruited. Further inclusion criteria included having engaged in a minimum of one-year of resistance training for two days per week, including the deadlift in the training cycle, able to deadlift at least 1.5 times their body weight and performed regular warmups before resistance exercise bouts.

Protocol

All data was collected and recorded by trained research personnel. The participation of subjects included three visits to the laboratory. Testing sessions were performed in a randomized, counterbalanced order at least five days apart but no more than one week apart at approximately the same time of the day (± 1 hour). All trials were performed in a climate-controlled, thermoneutral environment with ambient temperature and relative humidity maintained at 67-68°F and 55-60%, respectively.

For the first visit, all participants arrived at the university laboratory for familiarization. Participants were given adequate time to read and sign the Institutional Review Board (IRB) informed consent prior to data collection and questions from the participant were answered by the research team. After signing the written informed consent, participants completed a medical history questionnaire, which assesses if the individual is physically healthy to perform physical exercise (i.e., less than two risk factors for cardiovascular disease). Then, anthropometric data was collected, which included height, weight, waist and hip circumference, and body fat percentage. Next, participant's maximal voluntary contraction (MVC) for the gluteus maximus, vastus lateralis, and the long head of biceps femoris using surface electromyography (sEMG) was assessed using manual resistance. Gluteus maximus MVC was assessed using prone bent-leg (90°) hip extension with manual resistance applied to the distal thigh (M. Brown et al., 2013; Contreras et al., 2015; Kang et al., 2013). For vastus lateralis MVC, participants sat on a gurney with the legs off of the ground at a knee angle of 60° flexion before extending the knee while manual resistance was placed on the distal tibia and on the hip to restrain hip movement (Adam & De Luca, 2005). For the biceps femoris long head, the participant laid prone with a knee angle of 60° flexion while manual resistance was placed on the calcaneus (Silva et al., 2013). For all three movements, participants were asked to push as hard as possible in each position for 4-5 seconds (M. Brown et al., 2013). Each participant performed one familiarization then three trials for each movement with about 90 seconds of rest between contractions. The greatest muscular activity for each respective muscle was recorded for the muscles MVC. Following these measurements, the participants were shown and asked to practice the exercises that were performed during the two GWUs to ensure proper form and understanding of the exercise techniques. Last, the participants were randomized into the order of GWU's for visits two and three.

General Warm-up Conditions

For the second and third visits, participants were asked to refrain from strenuous exercise, caffeine, and alcohol 24 hours prior to testing. Additionally, participants were instructed to arrive at the laboratory under a two-hour fast, to keep a diary of dietary intake the day before tests, and to replicate the same dietary intake on the testing days. When the participants arrived, she/he sat for five minutes, they were screened to determine if they had engaged in any prohibited activities, a heart rate monitor was attached to the bottom of their sternum, they completed a visual analog scale assessing their fatigue index, perceived strength, and feelings of recovery (Carifio & Perla, 2008; Norman, 2010). For both conditions, the GWU differed and the SWU was identical. For condition A, participants completed the traditional GWU and for condition B, the participants completed the novel HIFT GWU. Previous research suggests beneficial effects of longer (15-minute) GWU's on 1-RM performance (Barroso et al., 2013; Stewart et al., 2003). Therefore, 15 minutes was used as the duration for both protocols, with about two minutes rest between the GWU and starting the SWU. The two GWU protocols were as follows:

Condition A (Traditional GWU)

15 minutes of cycling on the Monark cycle ergometer (Monark, Langley, WA) at 55-60% of participants maximal heart which has been tested elsewhere (Barroso et al., 2013) and supported by others (Bishop, 2003; Liguori, 2020).

Condition B (HIFT GWU)

15 minutes to complete as many rounds and reps as possible of row (females: 200-meters, males: 250-meters), 5 burpees, 10 kettlebell swings (males: 50 pounds; females: 35 pounds), 15 air squats. The row included using a row ergometer machine (Concept 2; Morrisville, Vermont) to pull a handle with a cable while sitting in a movable seat and pulling with the hips, knees, and arms to gain calories in the row. The burpee included lowering down to the ground so that the chest and hips touch the ground then standing up and jumping in the air with overhead, and trunk, hips, and knees fully extended. The kettlebell swings included swinging a single kettlebell from between the legs to an eye-level position with elbows completely extended. The air squats included raising one's center of mass from a seated (knees below hips) to a standing position, with trunk, hips and knees completely extended. The participants were asked to work as hard as possible to complete as many rounds and

reps as possible for the 15-minute duration.

Specific Warm-up

The SWU utilized was adopted from the warmup preceding 1-RM attempts in Haff & Triplett, (2021).

Measurements

Height was measured to the nearest half inch via a stadiometer (TANITA HR-200) and weight was measured to the nearest half pound via a digital scale (TANITA, BWB-800). Waist and hip circumference was measured to the nearest half inch via Gulick measuring tape (Perform Better!, West Warwick, RI). Body fat was assessed via the 7-site skinfold test using Lange skinfold calipers (Perform Better!, West Warwick, RI). Rating of perceived exertion (RPE) was assessed using a scale (RPE, Borg 6-20) (Borg, 1982). Heart rate was assessed using a chest worn monitor (Polar H10, Polar, Lake Success, NY). Moreover, the rounds and repetitions completed for the HIFT GWU were recorded.

The primary dependent variables measured included the maximal weight lifted, the maximum force and power generated, and the greatest neuromuscular recruitment of the gluteus maximus, vastus lateralis, and biceps femoris muscles using the sEMG (Barnes et al., 2017) for a single repetition on the conventional deadlift exercise. The sEMG was used because force production in skeletal muscles is due to electrical activation of motor units, which can be assessed using sEMG. This is done by placing electrodes on the skin of muscles being activated for the movement. Therefore, sEMG measurement is a method for noninvasive force estimation (Simon et al., 2024; Vredenbregt & Rau, 1973). The 1-RM was measured based on how much weight the participant could maximally lift during the conventional barbell deadlift using an Olympic barbell (Ohio 2.0 barbell, Rogue, Columbus, OH). The participant initiated the lift with the plates on the ground and the lift was completed when the trunk, hip, and knees were fully extended with the bar in the participant's hands. The load was increased incrementally until participants could not complete the lift. To measure maximal force and power output, a TENDO unit (TENDO Sport, London, U.K.) was attached to the end of the barbell. Muscle recruitment was measured on the participants' dominant leg muscles, including gluteus maximus, vastus lateralis, and long head of biceps femoris muscles via a sEMG unit (BIOX-4, iWorx, Dover, NH). Preceding electrode placement, the area was measured, shaved, and cleaned with an alcohol pad. The electrodes were placed on the mid-belly of the muscle parallel to the direction of the muscle fibers (Hermens et al., 2000). Raw EMG data were smoothed and rectified over 100 milliseconds (root mean square algorithm) (Cochrane & Barnes, 2015).

Statistical Analyses

Data analyses were performed using Statistical Packages for the Social Sciences (SPSS) version 28. Paired-samples, two-tailed, t-tests were used to assess the difference of the dependent variables between the TRAD and HIFT GWU. Differences between the TRAD and HIFT GWU conditions were assessed among females, among males, and combined sexes. Cohen's d was utilized to report the effect size, and 95% confidence intervals (CI) were calculated. In addition, differences between the second and third visit, despite the condition were analyzed for females, males, and combined sexes.

RESULTS

A total of 20 participants (n = 10 females) completed the study. Previous investigations utilizing similar measures and outcomes included between six and 15 participants (Ribeiro et al., 2021). There were no differences (all $p \geq 0.52$) in 1-RM, force, power, velocity, or muscular activity between visits two and three, despite the condition. In other words, neither the first nor second trial exhibited a difference in performance measures. This ensures there was not a learning effect bias between the first and second days of 1-RM attempts.

Demographics and anthropometrics are presented in Table 1. Among females, there were no differences in 1-RM, force, power, velocity, or muscular activity (all $p \geq 0.06$) between the conditions (Table 2). There was significantly greater ($p < 0.001$) heart rate (mean ± SD) (HIFT: 175 ± 9 bpm; TRAD: 115 ± 5 bpm) and RPE ($p < 0.001$) (HIFT: 15 ± 1 bpm; TRAD: 10 ± 2 bpm) immediately after the HIFT compared with the TRAD warmup (Table 2). The results among males demonstrated no differences in 1-RM, force, power, velocity, or muscular activity (all $p \geq 0.08$) between the conditions (Table 3). There was significantly greater heart rate ($p < 0.001$) (HIFT: 170 ± 21 bpm; TRAD: 118 ± 6 bpm) and RPE ($p < 0.001$) (HIFT:16 ± 1; TRAD: 9 ± 2) immediately after the HIFT compared with the TRAD warmup

Table 1. Participant Anthropometrics.

Variable	Mean	SD
Ethnicity: 14 white 4 black 1 Asian/white 1 Hispanic/white	N/A	N/A
Age (years)	21	2
Height (in)	66.9	21.2
Weight (lbs)	168.7	36.3
BMI	26.3	4.4
Waist-to-hip Ratio	0.82	.07
Body Fat (%)	15.8	5.3

Table 2. Mean ± SD values for females.

Parameter	TRAD	HIFT	*p*-value	Cohen's *d*	95% CI
1-RM (lbs)	210 ± 48	210 ± 44	0.90	0.043	-0.578, 0.662
Force (N)	1075 ± 439	985 ± 224	0.29	0.36	-0.292, 0.990
Power (W)	445 ± 103	498 ± 113	0.23	0.41	-1.047, 0.248
Velocity (m/s)	0.47 ± 0.17	0.53 ± 0.09	0.30	0.35	-0.984, 0.297
%MVC Gluteus Maximus	79 ± 49	84 ± 37	0.79	0.08	-0.706, 0.536
%MVC Vastus Lateralis	†96 ± 51	113 ± 49	0.06	0.68	-1.352, 0.031
%MVC Biceps Femoris	88 ± 43	91 ± 32	0.79	0.10	-0.706, 0.536
Heart Rate (bpm)	*115 ± 5	175 ± 9	<0.001	6.59	-9.636, -3.537
Rating of Perceived Exertion	*10 ± 2	15 ± 1	<0.001	2.33	-3.546, -1.091

**Statistically less than HIFT*

†Trending towards significantly less than HIFT

Table 3. Mean ± SD values for males.

Parameter	TRAD	HIFT	*p*-value	Cohen's *d*	95% CI
1-RM (lbs)	370 ± 72	360 ± 73	0.22	0.42	-0.237, 1.061
Force (N)	1711 ± 373	1777 ± 302	0.49	0.23	-0.815, 0.389
Power (W)	596 ± 230	676 ± 171	0.38	0.29	-0.919, 0.349
Velocity (m/s)	0.40 ± 0.12	0.40 ± 0.09	0.91	0.04	-0.584, 0.656
%MVC Gluteus Maximus	†80 ± 40	107 ± 56	0.08	0.63	-1.304, 0.064
%MVC Vastus Lateralis	76 ± 28	66 ± 34	0.40	0.28	-0.361, 0.905
%MVC Biceps Femoris	103 ± 70	116 ± 98	0.71	0.12	-0.737, 0.507
Heart Rate (bpm)	*118 ± 6	170 ± 21	<0.001	2.27	-3.451, -1.049
Rating of Perceived Exertion	*9 ± 2	16 ± 1	<0.001	3.53	-5.234, -1.802

**Statistically less than HIFT*

†Trending towards significantly less than HIFT

(Table 3). When combining the female and male participants, there were no differences in 1-RM (p = 0.22, Cohen's d = 0.28, CI: -0.171, 0.723; Figure 1), force (p = 0.85, Cohen's d = 0.04, CI: -0.395, 0.482; Figure 2), power (p = 0.17, Cohen's d = 0.32, CI: -0.764, 0.135; Figure 3), velocity (p = 0.36, Cohen's d = 0.21, CI: -0.650, 0.236; Figure 4), gluteus maximus MVC (p = 0.16), Cohen's d = 0.33, CI: -0.773, 0.128; Figure 5), vastus lateralis MVC (p = 0.12, Cohen's d = 0.12, CI: -0.559, 0.320; Figure 5), or MVC biceps femoris (p = 0.66, Cohen's d = 0.10, CI: -0.5339, 0.430; Figure 5). There was significantly higher heart rate (p < 0.001, Cohen's d= 3.14, CI: 4.296, -2.095; Figure 6) in the HIFT condition (172 ± 16 bpm) compared with the TRAD condition (116 ± 5 bpm) immediately after the respective warmup. In addition, there was significantly higher RPE (p < 0.001, Cohen's d = 2.85, CI: -3.839, -1.841; Figure 7) in the HIFT condition (15 ± 1) compared with the TRAD condition (9 ± 2) immediately after

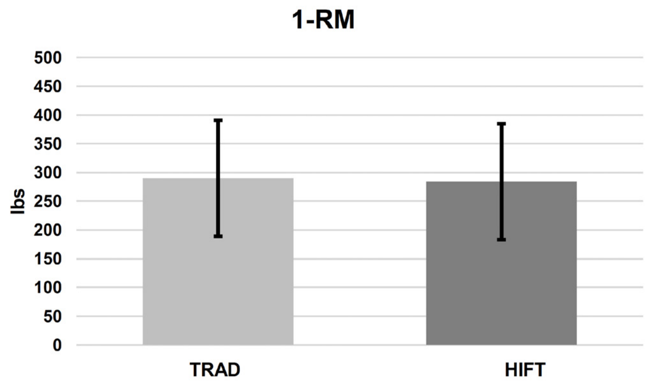

Figure 1. Combined males and females maximal load lifted post warmup in TRAD versus HIFT (mean ± SD)

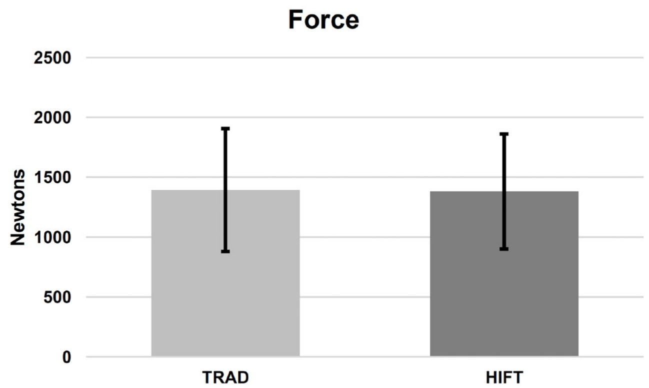

Figure 2. Combined males and females maximum force during 1-RM lift in TRAD versus HIFT (mean ± SD)

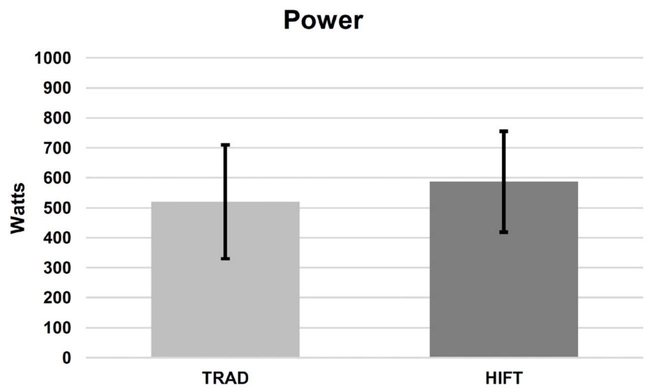

Figure 3. Combined males and females maximum power during 1-RM lift in TRAD versus HIFT (mean ± SD)

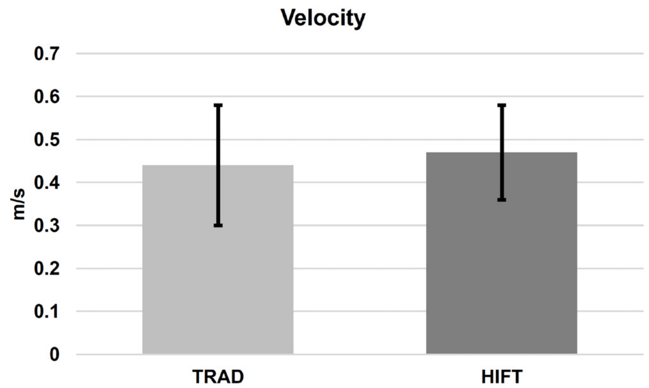

Figure 4. Combined males and females maximum velocity during 1-RM lift in TRAD versus HIFT (mean ± SD)

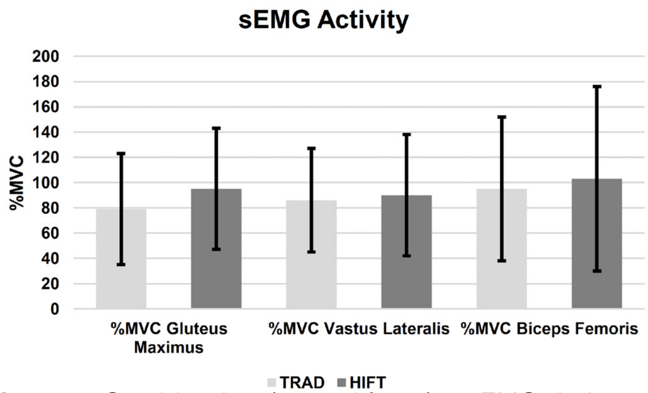

Figure 5. Combined males and females sEMG during 1-RM attempt in TRAD versus HIFT (mean ± SD)

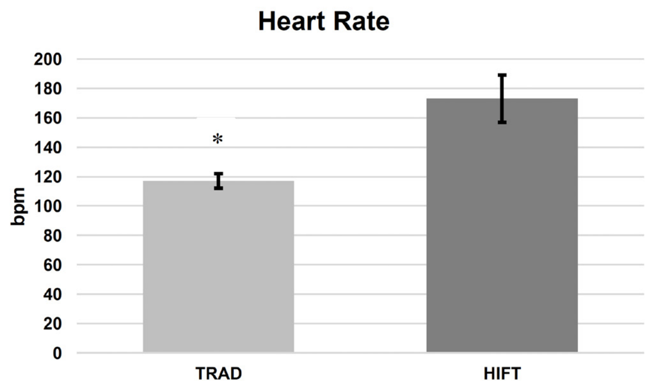

Figure 6. Combined males and females heart rate in TRAD versus HIFT post warmup (mean ± SD)
**Statistically less than HIFT ($p = < 0.001$)*

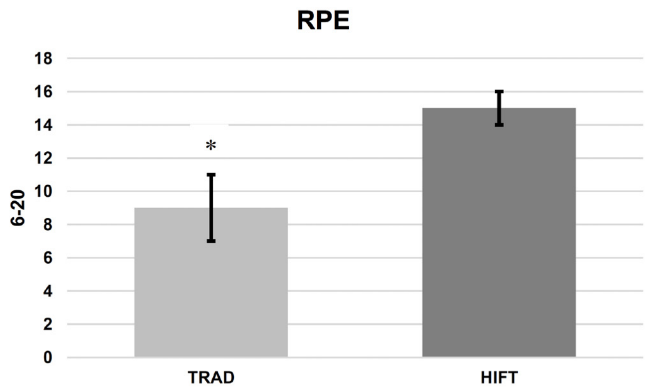

Figure 7. RPE in TRAD versus HIFT post warmup (mean ± SD)
**Statistically less than HIFT ($p = < 0.001$)*

the respective warmup. Of note, female's vastus lateralis %MVC was approaching significance (p = 0.06) with greater values in the HIFT compared with TRAD (HIFT: 101 ± 50%; TRAD: 96 ± 51%) and males gluteus maximus %MVC was approaching significance (p = 0.08) with greater values in the HIFT than the TRAD condition (HIFT: 107 ± 56%, TRAD: 80 ± 40%).

DISCUSSION

The present investigation introduced a novel GWU which consisted of a HIFT workout of vigorous exercise, compared with a traditional GWU to assess differences in 1-RM performance, force output, power output, and neuromuscular activity of the barbell conventional deadlift. The results demonstrated no differences in 1-RM, force output, power output, or neuromuscular activity between the two GWU conditions. However, there was higher heart rate and RPE immediately following the finish of the HIFT compared with the TRAD warmup protocol. These results suggest athletes may complete high-intensity aerobic and full body movements before performing heavy resistance exercise without a detriment in strength.

It has been previously suggested that an intense aerobic element preceding 1-RM testing may promote early fatigue and decrements in later performance testing (Barroso et al., 2013; Bishop, 2003) due to the decreased high-energy phosphates (Powers et al., 2021; Sale et al., 1990). Therefore, the current recommendations are to complete high-intensity aerobic activity subsequent to strength training and/or one-repetition maximum performance (Powers et al., 2021). However, in the current investigation, the HIFT condition averaged a heart rate of 90% of maximum at the end of the 15-minute workout. Within 12-15 minutes of the completion of the HIFT workout (time to complete the SWU), participants performed a 1-RM on the conventional deadlift. No differences were demonstrated between this 1-RM and a condition which utilized a time equivalent warmup at 55-60% of heart rate max. Because there were non-significant findings between the conditions for the variables 1-RM performance, force output, power output, and neuromuscular activity between the two conditions, which may suggest that vigorous aerobic activity preceding maximal strength efforts may not be deleterious to force production.

Several studies have found differing results when compared to the present investigation. These studies utilized GWU routines preceding 1-RM performance which included different durations and intensities of single modality, aerobic work (Abad et al., 2011; Barnes et al., 2017; Barroso et al., 2013; L. E. Brown & Weir, 2001; Firat et al., 2018; Fırat & Dicle, 2018; Stewart et al., 2003). In one investigation by Abad, (2011), participants cycled for 20 minutes at approximately 60% of their maximal heart rate, due to research suggesting that muscle temperature increases after 15 to 20 minutes (Bishop, 2003; Davies et al., 1982; Price & Campbell, 1997), and then completed a SWU for the leg press. This study found the longer-duration, low-intensity GWU elicited a greater 1-RM on the leg press than a shorter duration low-intensity GWU protocol (Abad et al., 2011). Barosso, (2013) demonstrated long duration (15 minutes), low-intensity (40% VO^2_{max}; 55% of maximal heart rate) cycling elicited the greatest 1-RM compared with long duration moderate-intensity (70% VO^2_{max}), short duration (5 minutes) low-intensity, and short duration moderate-intensity. The results of this study suggest the improvements were due to the longer duration potentially improved muscle blood flow while the moderate-intensity impaired performance because of too much blood lactate accumulation (Barroso et al., 2013). Other investigations have manipulated the intensity of single modality, aerobic warm-ups using the rowing ergometer on 1-RM performance (Firat et al., 2018; Fırat & Dicle, 2018). These studies concluded that a 15-minute low-intensity warm-up with short bouts of supramaximal sprints in the last five minutes of the warm-up improved bench press and leg press 1-RM performance. Furthermore, Wilcox, (2006) demonstrated that using an explosive warmup consisting of plyometric push-ups or medicine-ball chest passes improved performance on a barbell bench press 1-RM. Together, these previous investigations on warmups preceding 1-RM performance suggest a GWU of lower-intensity aerobic warmup, with potential short sprints or explosive movements for the aerobic modality may improve 1-RM performance.

The current investigation's results differ from Abad, (2011), Barosso, (2013), Firat (2018), and First & Dicle, (2018), in that there were no differences between a HIFT workout and traditional warmup on 1-RM performance. Moreover, the variables that were approaching significance and exhibited moderate-to-large effect sizes (female's vastus lateralis %MVC and males gluteus maximus %MVC) were greater in the HIFT than the TRAD condition. A higher percentage of MVC during the lift means there was greater neuromuscular recruitment. Greater neuromuscular recruitment is involved with greater force production (Simon et al., 2024; Vredenbregt & Rau, 1973). This result suggests the HIFT warmup may have elicited slightly greater muscular recruitment, which would allow greater muscular force generation.

LIMITATIONS AND FUTURE RECOMMENDATIONS

Although this is a novel warmup protocol preceding a 1-RM, it is not without limitations. First, the study is limited to healthy adults aged 18-25 years old. Second, muscle temperature, hormone levels, and adrenaline were not assessed. Third, this study is limited to the warmup and 1-RM protocols that were implemented. Fourth, we did not control for female's menstrual cycle, because two studies suggest menstrual cycle does not affect strength performance (García-Pinillos et al., 2022; Romero-Moraleda et al., 2019). Fifth, we did not assess the warmups in which participants engaged preceding their personal resistance exercise bouts, as there may be variation which could affect responses to the warmups performed in this study. Lastly, there may be a difference in individuals' ability to lift heavy loads based on their conditioning status. To address these limitations future studies should assess a wide range of individuals, including HIFT (i.e., CrossFit) athletes and different ages, assess biochemical factors, objectively measure aerobic conditioning of the participants, and include warmups with more variations in exercises, sets, rest periods, etc.

CONCLUSION

This study introduced a novel protocol to implement preceding warming up for 1-RM attempts, which included performing a bout of HIFT. The results demonstrated no differences in 1-RM, force output, power production, or muscle activity when comparing a traditional warmup to one which includes a HIFT workout. Furthermore, heart rate and perceived exertion were higher following the high-intensity functional training warmup, which demonstrates higher intensity of exercise. Therefore, the authors suggest coaches and athletes who perform concurrent aerobic and resistance training in the same session should feel confident in engaging in high-intensity aerobic activity before heavy resistance exercise because the aerobic portion may not negatively affect strength outcomes. In addition, performing a bout of higher intensity exercise before heavy resistance exercise may be a useful modality order for those who do not engage in regular aerobic exercise, since there may be greater health benefits to engaging in higher intensities of activity.

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CONFLICTS OF INTEREST

The authors report there are no competing interests to declare.

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ETHICAL APPROVAL

This study was approved by the Human and Animal Subjects Research Committee at the University of Montevallo (#CFetal101223). All the procedures in this study were in accordance with the 1975 Helsinki Declaration. Informed consent was obtained from all participants included in the study.

STUDY ASSOCIATION

This study is not associated with any thesis or dissertation work. It is associated with the TRIO McNair Scholars program, which is not a peer-reviewed source. Some of the data has been presented in the McNair Scholars program for student research. However, the entire data set and full manuscript have not been previously published in a peer-reviewed journal.

DATA AVAILABILITY STATEMENT

This data is kept on a password protected server by the corresponding author.

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