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SCIENTIFIC RESEARCH

Neuromuscular Electric Stimulation as an Alternative to Dynamic Warm-Up for Anaerobic Power Activities

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Abstract

The aim of this study was to compare short duration Neuromuscular Electric Stimulation (NMES) to traditional dynamic warm-up to prepare muscles for activity. Thirty college age participants (20 male, 10 female) completed both a general warm-up, followed by either an NMES warm-up or a dynamic warm-up. The participants were then asked to perform three trials each of standing long jump, 20m sprint, and 18.3m (20-yard) shuttle run, in random order. Each participant returned one week later and were tested using the warm-up procedure that they had not performed the week before (repeated measures design). Intra-class correlation coefficients for the three dependent measures for each intervention ranged from 0.87 to 0.99, indicating overall excellent reliability within each measure. There was no difference between the warm-up procedures for the SLJ, 20m sprint, or 20-yard shuttle run tests. This inter-individual variation suggests that short duration NMES could be beneficial for some athletes, while some may find dynamic warm-up more effective. Based on the outcome of this study, athletes and coaches should experiment and determine what is best for the individual. Results from the research could help to determine NMES's use in strength and conditioning and as a means of performance enhancement.

Keywords

Potentiation, Movement, Sports performance, Muscle contraction, Quadriceps

Introduction

Warming up for an activity is intended to perform two functions: improve the muscles' dynamics so that the athlete is less inclined to injury and prepare the athlete for the demands of exercise. A warm-up should be specific to the exercise being performed, but in general intense enough to produce a mild sweat but not fatigue the individual [1]. While an extensive search for optimal warm-up protocols for aerobic activity did not yield any peer-reviewed research on the matter, a substantial number of studies have examined optimal warm-up protocols for anaerobic activities [2-6].

Among these various anaerobic-based studies, the primary recommendations include warm-up activities that include ballistic stretching and dynamic exercise, both which have been shown to increase performance in power, agility, sprint time, and vertical jump height. However, variations to these warm-up activities must be considered when seeking a means to improve performance. An example of an effective variation in a dynamic exercise is the treppe (i.e. staircase) method that can increase muscle fiber recruitment of the specific muscles used for the main activity [7]. An additional variation in dynamic warm-up for anaerobic activity is to optimize the stretch shortening cycle via isometric contractions where the muscle can be stretched up to 1.3% of its original length. This warm-up variation has been shown to help generate maximum power, yet not over stretch the muscle [8]. Isometric contractions may also encourage Post Tetanic Potentiation (PTP). PTP is activated by causing a maximal involuntary contraction of the muscle, then removing the stimulus, releasing the contraction and performing a concentric movement with that muscle. Studies examining the length of post-conditioning rest periods have conflicting results. However, a range between 3 and 10 minutes appears to yield optimal power output [9,10]. Furthermore, the influence on PTP appears to be dependent on both the

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training status and the conditioning activity. Specifically, the effects of PTP appear to be much greater on athletes than on untrained or trained individuals, as well as on lower body dynamic and static activities, compared to dynamic upper body activities [11]. PTP along with high frequency initial pulses have been shown to increase muscle performance during one or a series of submaximal contractions [12]. This physiological outcome mimics the intended effects of an anaerobic warm-up.

Neuromuscular Electric Stimulation (NMES) is commonly used in rehabilitation settings primarily for pain modulation and muscle reeducation [13]. NMES has also been shown to be effective to enhance an individual's training regimen when used consistently over a period of time [14]. On a theoretical basis, NMES can potentially be used as a means for warming-up via PTP. It is postulated that one mechanism of PTP is through phosphorylation of myosin regulatory light chains during tetanic contractions, which renders actin-myosin more sensitive to calcium released from the sarcoplasmic reticulum in subsequent contractions [15]. Another theory is through neural mechanisms such as reflex potentiation, this is an enhanced muscle response to an afferent neural volley. The increase volitional force production could be from increased reflex transmission between I_a afferents and x-motoneurons [16]. Furthermore, the central nervous system may be able to optimize the descending reflex contribution through repeatedly producing a reflex potentiation to result in greater neural drive to the trained muscle [17]. Unlike voluntary muscle contractions produced during traditional warm-up activities, NMES is not selective in the fiber type it stimulates [18], which could result in a warm-up that targets the various muscle fiber types simultaneously. The effects of NMES and PTP on muscle performance have only been examined with upper body muscle groups. Specifically, no significant bench press performance increases from NMES on PTP were found and may have been partially due to large inter-individual differences [15].

An extensive search found no empirical studies adopting NMES as part of a warm-up protocol for improving functional performance (e.g. jumping, running). Twitch potential and reflex potentiation were examined in both the quadriceps femoris muscle [16] as well as the gastrocnemius and soleus muscle groups [19]. Albeit both studies employed voluntary contractions, the idea of a neural connection to PTP in the form of reflex potentiation could hold true for involuntary contractions. There have been claims that portable muscle stimulators have positive effects on potentiation, and companies have incorporated specific warm-up programs into their machines, but without proper empirical evidence, these claims can result in potential adverse effects. The purpose of this study is to examine the effects of electro-muscular stimulation during warm up on lower body functional performance. Based on previous research, it was hypothesized that adopting NMES will have similar outcomes to a traditional warm-up in terms of functional performance.

Methods

Participants

Thirty NCAA division III athletes (20 male, 10 female) volunteered to participate in this study. M ± SD for age, height and weight for the male participants were 19.8 ± 1.5 years, 180.4 ± 9.5 centimeters, 88.0 ± 11.4 kilograms, respectively, and 19.7 ± 1.1 years, 161.1 ± 5.8 centimeters, 62.7 ± 7.1 kilograms for the female participants. Participants were screened for both general health issues (using the PAR-Q questionnaire) and lower extremity injuries within the past 6 months prior to participation. Those with potential risk for injury were excluded from the study. Each participant was informed about the benefits and risks inherent in this research, and signed an institutionally approved informed consent form prior to participating.

Prior to the study, an *a-priori* power analysis was performed using G*Power (version 3.1.9.2; Brunsbüttel, Germany) [20]. Using a moderate effect size of 0.6 [21], an alpha level of .017 (see explanation statistical analysis section), and a power of 0.80, the required sample size of 30 was calculated for a two-tailed *t*-test with repeated measures.

Protocol

For comparison purposes, the general warm-up protocol was akin to that of a previous study [5]. Specifically, the warm-up included a 2-minute jog, 30 seconds of side steps, 30 seconds of back pedals, and a 1-minute jog. The participants were asked to complete the general warm-up at a rate of perceived exertion of 12 on the Borg scale [22]. Upon completion, the participant then rested for 4 minutes.

The protocol used for the dynamic warm-up was similar to the one suggested for quadriceps and hip flexors [4]. Specifically, the participant was asked to perform three movements, for 40 meters each. The warm-up movements were performed continuously and included forward lunges with forearm to instep, backward lunges, and butt kicks. Each participant was timed to ensure duration was similar to that of the Neuromuscular Electric Stimulation (NMES) warm-up (approximately 210 seconds). The participant then rested for three minutes prior to starting the three functional tests.

For the NMES warm-up, a Compex sport elite muscle stimulator (Compex; Vista, CA) was used. Electrodes were placed on the participants' thigh muscles, one double pad near the origin of the vastus lateralus and

Figure 1: Electrode pad placement and participant position (according to manufacturer instructions).

vastus medialus. A small pad was also placed near the insertion of the vastus lateralus and vastus lateralus muscles (Figure 1). The electrostimulation machine was set to an intensity such that the participant noted a strong stimulation that was not painful. The preset "potentiation" (warm-up) program from the machine was used and took 207 seconds to complete. This program has 10 frequency spikes of 2, 10, 15, 20, 25, 35, 45, 55, 65, 75 Hertz during the tetanus phase, each lasting 7 seconds and an in between phase of 1 Hertz. The participant then rested for three minutes prior to starting the three functional tests.

The three functional tests [23] were used to compare between the two warm-up protocols. The functional tests involved the Standing Long Jump (SLJ), 20 meter sprint, and 18.3 meter (20-yard) shuttle run. SLJ was performed by having the participant stand with their toes behind a line and asking them to jump as far as they can. The distance from the toe line to the heel closest to the toe line was measured. For the 20 meter sprint, a "3, 2, 1, go" command was used. On "go" time was started, and participants started their sprint, running through the 20 meter mark.

The shuttle run was measured by placing a piece of tape on the floor, two more pieces of tape were measured out at 5 yards in either direction from the center tape. The participant was asked to start by straddling the centerline with their hand on the line. At the command of the examiner, the participant ran to the line of their choosing, then back through the centerline to the other line (10 yards away), then back through the centerline. Time was stopped the when the participant ran back through the centerline. All times for the sprint and shuttle run were measured to the nearest 0.1 second. Each functional test was performed three times with a 1-minute rest between trials, and 2-minute rest was given between each functional test.

Statistical analysis

A paired samples two-tailed *t*-test was used to determine whether there were any significant differences found between the two independent variables (dynamic vs. NMES warm-up) on the three dependent variables (SLJ, sprint, shuttle run), separately. A Bonferroni correction was used to reduce type 1 errors. Therefore, alpha was set to 0.05/3 = 0.017. Confidence intervals were calculated for the differences between the means between the two independent variables, for all three dependent measures (1.00-alpha = 0.983%). Cohen's d was calculated to determine effects size for each *t*-test (Cohen, 1982). Intra-class correlation coefficients were calculated for the three trials of each of the dependent variables and intervention, separately. All statistical analyses were performed using SPSS (version 26; Armonk, NY).

Results

Intra-class correlation coefficients for the three dependent measures for each intervention ranged from 0.87 to 0.99, indicating overall excellent reliability within each measure [24]. Of the 30 participants, 17 performed better in the Standing Long Jump (SLJ) with the dynamic warm-up, whereas 13 performed better after NMES. The differences between the SLJ between interventions (dynamic vs. NMES) were minimal and no significant differences were found, $t(29) = 0.36$, $p = 0.72$. Furthermore, the standard deviations between the two interventions were similar, indicating consistency in warm-up type (Table 1). The effect size calculated (0.01) showed trivial effects [21], suggesting factors other than warm-up type caused the differences between the interventions.

Repeated measures *t*-test found no significant difference in the averages for the 20 meter sprint times between dynamic and NMES warm-up groups, $t(29)$ =

Table 1: M ± SD of Standing Long Jump (centimeters), 20 meter Sprint (seconds), 18.3 meter (20 yard) Shuttle Run (seconds); CI = Confidence Interval; Effect size measured using Cohens d.

	Dynamic	Stim	CI	Effect Size
SLJ	195.6 ± 35.9	197.2 ± 36.6	(-5.00, 7.34)	0.04
Sprint	3.6 ± 0.3	3.5 ± 0.4	(-0.14, 0.12)	0.18
Shuttle	5.5 ± 0.5	5.4 ± 0.6	(-1.00, 0.25)	0.15

0.88, p = 0.39. Both the mean and standard deviations between the groups was nearly identical. An equal number of participants (n = 15) performed better after the dynamic warm-up as NMES. Cohen's d for this measure was calculated to be 0.18, indicating a small effect size.

Both average and standard deviation shuttle run times between the dynamic and NMES warm-ups were near identical. However, 13 participants performed better after dynamic warm-up whereas 17 performed better after NMES. Repeated measures t-test found no significant differences found no significance, p (29) = 0.97, p = 0.34, and effect size was found to be trivial (0.04).

Discussion and Conclusions

The objective of this study was to determine if warming-up utilizing NMES had any benefits to lower body anaerobic performance over warming-up with traditional dynamic exercises. Overall, the results of this study show that there was no difference in functional performance between the two warm-up methods. Dynamic warm-up was chosen because it is known to reduce the chance of injury in athletes [25] as well as being an established means to prepare the body for physical activity and optimize athletic performance when compared to static stretching alone [3,6]. Benefits to performance are recognized at a variety of performance benchmarks including: Vertical jump, power, agility, and even greater electromyographic activity during maximal voluntary contraction [2].

The utilization of NMES on the quadriceps muscles has been demonstrated to elicit a cardiovascular response, even though the contractions were not voluntary [26]. NMES also benefits performance by not affecting stretch shortening cycle negatively because the muscles are contracting isometrically and not elongating. The negative effects to the stretch shortening cycle from NMES would be minimal because the muscle only stretches to 3% of its resting length [27]. NMES could also work at a neurologic level since PAP is thought to occur in the level of the spinal cord as well as the muscle, this is through increased synaptic efficiency [8], as well as the muscular level by making actin and myosin more responsive to Ca^{+}. Although PTP was not measured in this research, it is importance to discuss. These factors could have benefits to performance by providing what has been shown to be an ideal warm-up [1], as well as attribute to similar outcomes found in this study between the NMES and dynamic warm-up group.

The effect size for the three functional performance measures was trivial. In this study, although the standard deviations were small, the mean differences between the groups were minimal. While both averages and standard deviations between NMES and dynamic warm-up were found to be nearly identical, there were inter-individual differences found. A number of the participants consistently performed better while using NMES while others had better performances with traditional dynamic warm-up. There seems to be no connection between the sport played and the outcome of the results, inter-individual differences could be due to muscle fiber make up and how the individual responds to the NMES.

Although NMES does not seem to have a more advantageous effect of warming-up muscles than traditional dynamic warm-ups, some athletes could still benefit from utilizing NMES before activity. In the SLJ measure, 13 of the 30 participants performed better with NMES warm-up than with dynamic, sprint was even with half the participants performing better with NMES. Finally, 17 participants performed better with NMES during the shuttle run trial. These differences may suggest that for some individuals, NMES could be more beneficial, while some may find dynamic warm-up to be more beneficial.

The outcome in this study is similar to a previous study that found no differences in bench press performance between NMES and PTP elicited by submaximal loads [15] although PTP was not measured in the current study. These similar outcomes can be attributed to the non-differentiation of muscle fiber type stimulation that NMES has been shown to illicit [18]. Both studies utilized active muscle contractions as a control, which follows the Henneman size principal [8,28]. Conversely, both NMES trials recruited motor units randomly. These similarities in the independent variables suggest that both methods of motor recruitment patterns appear to equally prepare the muscles for maximal voluntary contraction but in a different manner.

Limitations to this research include the use of only one NMES unit with a set protocol, it is feasible to assume that someone may respond differently with other parameters. Another limitation could be the order effect of the dependent variables, it could be beneficial to randomize the order of tests. Further research could assess the effects of long-term use of this modality to determine if the effects on warm-up are similar to the effects on power production over long-term use.

This study's outcome suggests that NMES can provide an adequate means to prepare the body for activity. NMESs effects on warm-up have been shown to provide greater twitch force in the knee extensor muscles, not negatively affect the stretch shortening cycle before ballistic movements, increase blood flow, and have neurologic and muscular advantages. However, the inter-individual results between participants suggest that while NMES seems effective for some, it may not be as effective as dynamic warm-up for others; future studies could examine this difference.

References

1. Woods K, Bishop P, Jones E (2007) Warm-up and stretching in the prevention of muscular injury. Sports Med 37: 1089-1098.
2. Chaouachi A, Castagna C, Chtara M, Brughelli M, Turki O, et al. (2010) Effect of warm-ups involving static or dynamic stretching on agility, sprinting, and jumping performance in trained individuals. J Strength Cond Res 24: 2001-2011.
3. Curry BS, Chengkalath D, Crouch GJ, Romance M, Manns PJ (2009) Acute effects of dynamic stretching, static stretching, and light aerobic activity on muscular performance in women. J Strength Cond Res 23: 1811-1819.
4. Fredrick GA, Szymanski DJ (2001) Baseball (Part I): Dynamic flexibility. National Strength and Conditioning Association 23: 21-30.
5. Little T, Williams AG (2006) Effects of differential stretching protocols during warm-ups on high-speed motor capacities in professional soccer players. J Strength Cond Res 20: 203-207.
6. McMillian DJ, Moore JH, Hatler BS, Taylor DC (2006) Dynamic vs. static stretching warm-up: The effect on power and agility performance. J Strength Cond Res 20: 492-499.
7. Burkett LN, Phillips WT, Ziuraitis J (2005) The best warm-up for the vertical jump in college age athletic men. J Strength Cond Res19: 673-676.
8. Hodgson M, Docherty D, Robbins D (2005) Post-activation potentiation: Underlying physiology and implications for motor performance. Sports Med 35: 585-595.
9. Kilduff LP, Bevan HR, Kingsley MIC, Owen NJ, Bennett MA, et al. (2007) Postactivation potentiation in professional rugby players: Optimal recovery. J Strength Cond Res 21: 1134-1138.
10. Smith J, Fry A (2007) Effects of ten second maximal voluntary on regulatory myosin light-chain phosphorylation and dynamic performance. J Strength Cond Res 21: 73-76.
11. Wilson JM, Duncan NM, Marin PJ, Brown LE, Loenneke JP, et al. (2013) Meta-analysis of postactivation potentiation and power: Effects of conditioning activity, volume, gender, rest periods, and training status. J Strength Cond Res 27: 854-859.
12. Abbate F, Sargeant AJ, Verdijk PWL, Haan ADE (2000) Effects of high-frequency initial pulses and postetanic potentiation on power output of skeletal muscle. J Appl Physiol 88: 35-40.
13. Chesterton LS, Barlas P, Foster NE, Lundeberg T, Wright CC, et al. (2002) Sensory stimulation (TENS): Effects of parameter manipulation on mechanical pain thresholds in healthy human subjects. Pain 99: 253-262.
14. Gondin J, Cozzone PJ, Bendahan D (2001) Is high-frequency neuromuscular stimulation a suitable tool for muscular performance improvement in both healthy humans and athletes? Eur J Appl Physiol 111: 2473-2487.
15. Bernardo R, Mikel Z, Juan R, Jaan E, Mati P, et al. (2005) Effects of post-tetanic potentiation of pectoralis and triceps brachii muscles on bench press performance. J Strength Cond Res 19: 622-627.
16. Folland JP, Wakamatsu T, Fimland MS (2008) The influence of maximal isometric activity on twitch and H-reflex potentiation, and quadriceps femoris performance. Eur J Appl Physiol 104: 739-748.
17. Trimble MH, Harp SS (1998) Post exercise potentiation of the H-reflex in humans. Med Sci Sports Exerc 30: 933-941.
18. Gregory CM, Bickel SC (2018) Recruitment patterns in human skeletal muscle during electrical stimulation. Phys Ther 4: 358-364.
19. Wallace BJ, Shapiro R, Wallace KL, Abel MG, Symons TB (2015) Muscular and neural contributions to postactivation potentiation. J Strength Cond Res 33: 615-625.
20. Faul F, Erdfelder E, Lang AG (2009) Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behavioral Research Methods 41: 1149-1160.
21. Cohen J (1992) A power primer. Psychol Bull 112: 155-159.
22. Borg GA (1982) Psychophysical bases of perceived exertion. Med Sci Sports Exerc 14: 377-381.
23. Markovic G, Jukic I, Milanovic D, Metikos D (2014) Effects of sprint and plyometric training on muscle function and athletic performance. J Strength Cond Res 21: 453-549.
24. Koo TK, Li MY (2016) A guideline of selecting and reporting intraclass correlation coefficients for reliability research. J Chiropr Med 15: 155-163.
25. Soligard T, Myklebust F, Steffen K, Holme I, Silvers H, et al. (2008) Comprehensive warm-up programme to prevent injuries in young female footballers: Cluster randomised control trial. BMJ 337: 1-9.
26. Banerjee P, Caulfield B, Crowe L, Clark A (2005) Prolonged electrical muscle stimulation exercise improves strength and aerobic capacity in healthy sedentary adults. J Appl Physiol 99: 2307-2311.
27. Nigg BM, MacIntosh BR, Mester J (2000) Biomechanics and biology of movement. Champaign, IL: Human Kinetics.
28. Henneman E, Somjen, G, Carpenter DO (1965) Functional significance of cell size in spinal motorneurons. J Neurophysiol 28: 560-580.