Neuromuscular Fatigue From Repeated Sprint Exercise and the Impact It Has on Jump Performance: A Pilot Study

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Abstract

In this work we present the preliminary results of the effects that a repeated sprint exercise has on neuromuscular fatigue. We focused on the repeated sprint ability of athletes with different training backgrounds (soccer, baseball, cross country,ect.) and considered how it may influence muscle fatigue. Jump mats were used to measure change in force output, peak power and impulse. Changes in sprint times were used to calculate a fatigue percentage decrement. It was found that there was no statistically significant change in peak power and impulse when comparing pre jumps, post jumps and post 10 minute jumps. There was also an average of 6.7% fatigue decrement, roughly half of what other similar studies had managed to achieve. The data gathered may be a result of using college athletes, meaning they were unable to reach the same fatigue level as other studies.

Introduction

RSA

Repeated sprint ability, or RSA, is defined as the ability to recover and reproduce performance in subsequent sprints. These short duration sprints with brief recoveries are commonly seen with team sports, such as soccer and are an important aspect of the fitness required for those athletes (Girad, 2011). RSA influences an athlete's ability to perform as fatigue development can be linked to the ability to repeat sprints, with RSA deteriorating quickly as fatigue develops. When dealing with RSE, a decrease in peak power or total work is seen over sprint repetitions, with research also finding that there is a positive correlation with performance decrement over subsequent sprints when compared to the initial sprint.

RSA varies with each individual, with many factors coming influencing the ability to perform repeated sprint exercises. Factors such as sex, age, training status and even the time of day can impact ones RSA. Limiting factors also play a role in RSA, including muscle excitability, phosphocreatine availability and neural drive. Along with these stiffness regulation and environmental factors can play a role in an individual's ability to repeat sprints (Bishop, 2011). RSA has a direct impact on athletes from a variety of sports and their ability to perform to their fullest. Factors influenced by RSA included speed and explosiveness, both important aspects to an athlete in a high intensity match (Girard, 2011). Focusing on improving RSA, or increasing one's resistance to muscle fatigue, can help improve late-game performance and enhance an athlete's ability to compete.

In the context of this paper, the sprint being performed falls under Repeated Sprint Exercise (RSE), which are characterized by short duration sprints typically lasting less than 10 seconds with a brief recovery of less than 60 seconds in between (Girard, 2011).

Fatigue

Fatigue in muscles is most often defined as the decrease in ability to perform physical actions, in both maximal force and power exerted, following a sustained physical activity. (Enoka, 2008)

Central fatigue on the other hand tends to be defined as an exercise-induced reduction in the ability to do a maximal voluntary contraction force that is not followed by the same reduction in maximal evocable force (Vøllestad, 1997). Peripheral fatigue can be defined as the decrease in ability to perform physical actions, such as maximal force and power exerted, following a sustained activity. In the context of RSE, fatigue cna defined as a reduction of maximal power output or speed, throughout the same exercise (Girard, 2011). With these short duration sprints, peripheral mechanisms play a bigger part in fatigue than neural factors (Bishop, 2012) Fatigue is not caused by a single issue, but instead is influenced by a number of variables and can be measured by multiple outputs. An overall reasoning for fatigue occurring is that one or several of the physiological processes that allow for the contractile proteins in muscles to generate force has become impaired, meaning less force is occurring over time (Enoka, 2008). It is also important to note that where fatigue is occurring relies heavily on the task being performed, since there is no singular cause of muscle fatigue, the dominant mechanism is specific to the processes being stressed during an exercise (Enoka, 2008). Along with this, variables such as age, sex, type of muscles and activation of msucles by the nervous system all play a role in the level of fatigue that will occur. For example, if muscle activation is adequate, it means additional force will be outputted to the muscle, leading to the development of fatigue quicker. Fatigue during RSE specifically can be influenced by the task occurring, the resistive load, the running surface, the distribution and duration of the work periods and the recovery patterns (Girard, 2011). Fatigue during RSE can be attributed to limitations in energy supply, such as VO2 and metabolic by-product accumulation, such as H+. Following an exercise that requires the maximal force or power capacity of a muscle to decline, fatigue in muscles begins. If the task requires sustaining a maximal contraction, the decline in performance will match with an increase in fatigue, however it should be noted that if the task requires a submaximal contraction, the fatigue will probably not stop once the exercise is complete. With intensive activity, fatigue will occur, which will cause a decline in performance (Enoka 2008).

Fatigue decrement captures the decline in muscle power and force output during physical activity. The reliability of these scores and quantifying of fatigue can be tricky and may be unreliable. There are many factors that can impact fatigue, making it difficult to find a formula or process that can accurately measure fatigue similarity across multiple instances (Glaister, 2008). With repeated sprint exercises (RSE), fatigue can be onset quickly as seen with a decline in maximal sprint speed over sprint repetitions. To measure this onset of fatigue, the use of the percentage decrement score can be used to measure and quantify fatigue by comparing the actual perfromal to an ideal performance, meaning the best effort would be seen with each sprint. With the percentage decrement score, it takes into consideration all sprints that occur, making a more reliable method than some for testing RSA (Glaister et al. 2008). Using fatigue scores allows for a more reliable eaument of performance reduction during an RSE test. The most reliable formula for measuring this decrement includes the mean sprint time and the fastest sprint time (Oliver et al., 2006; Glaister et al., 2008).

Jump Performance

When quantifying neuromuscular fatigue, the vertical jump (VJ) can be implemented as a way to measure lower-body power. It has been found that neuromuscular function decreases following an activity that fatigues the knee extensor group leading to decreases in several variables of countermovement VJ, with factors such as average flight time over consecutive jumps and the ratio of flight time to contraction time being impacted the most (Watkins, 2017).

Countermovement jump testing is the most suitable for monitoring neuromuscular fatigue due to the high repeatability and immediate and prolonged fatigue-induced changes (Gathercole, 2015). When repeated sprints are done, research has been found that presents significant and large decreases in performance, with a significant decrease in the capability to both produce total force and the ability to apply it (Morin, 2011).

Force through a vertical jump can be measured using a force plate, where the individual stands still on the plate and then jumps as high as possible with their hands staying on their hips. The subject performed two trials, but, if they continued to jump higher, they then jumped till height stabilized. From this, the two highest jumps were taken and averaged (Watkins, 2017).

Peak power output (PPO), also known as peak work rate, is a way of measuring the intensity of a workout. In determining the PPO during a CMJ, the jump mat calculates the output by using a formula involving the subjects body weight and their vertical jump height. Impulse is the measurement of the net upward impulse of each athlete or the net upward momentum, or how long it takes a subject to jump off the mat and the effort needed to jump (Fusion Sport).

Jump performance can accurately show the decrease in force output and the fatigue an athlete is experiencing following an RSE test, meaning there can be a better understanding of their individual fatigue levels. By knowing an individual athlete's performance ability, a coach can use the data as a tool to implement training and sessions designed to target areas that need improvement for each player. A coach can also use their jump performance as a gauge for how ready their players are to perform a certain task (Watkins et al., 2017).

Material and Methods

Subjects

Seven healthy subjects (men n = 3; mass = 72.67 ± 5.03 kg; height = 182.33 ± .57 cm; age = 21 ± 1 years) (women = 4; mass = 72.75 ± 6.99; height = 164.75 ± 3.5 cm; age = 20) volunteered to participate in this study. All subjects were physically active and had all participated in physical activities that included sprints or distance running in the past 6 months (e.g. soccer, basketball, cross country) before the study took place. They were instructed to not perform any outside exercise 24 hours prior to testing that would result in the fatiguing of the muscles aside from their daily routine.

Surface Electromyography Setup

Four sEMG electrodes were placed on the subject's leg over the rectus femoris, gluteus maximus, biceps femoris and medial head of the gastrocnemius. Before attaching the electrodes, the area was shaved, lightly abraded using a disposable skin defoliator and was then rubbed down with an alcohol swab. The electrodes were attached to the skin with adhesive, both in the form of two-sided electrode tape and athletic tape placed over the electrode and leg. Subjects were encouraged to wear spandex tights, half-tights, or other similar clothing as an added measure to secure electrodes. SEMG was recorded on 4 channels using a wireless Delsys Tringo EMG (Delsys Incorporated, Natick, MA, USA) system.

Instrumental Setup

Timing Gates

An inclined hill was measured for a distance of 30 meters, and was calculated to have an average slope of approximately 4 degrees or 7%. At the start and end of the 30 meters, gates were placed to measure the duration of each sprint. The SmartSpeed gates and timing system recorded sprint time to the thousandth of a second.

Jump Mat

A SmartSpeed mobile jump-mat was positioned near the end of the sprinting area for quick access after sprints were completed. The jump mat shared the same SmartHub as the timing gates in order to minimize costs as well as inter-equipment variability. The timing gates had to be disconnected from the SmartHub before the jump mat could be used, meaning that a standardized 30 second recovery period was given to subjects after their final sprint in order to allow for the switch. To obtain jump mat data, the SmartSpeed jump mat (Fusion Sport, Broomfield, Colorado, USA) was used.

Experimental Session

For the testing session, the aerobic warm-up consisted of 5-10 minutes of self paced jogging on a motorized treadmill followed by 20 jumping jacks and 10 body weight squats. Subjects then conducted 3 counter movement jumps, with a progression of 50%, 75% and 90% effort. They then conducted 4, 15 meter incline sprints, two at 50%, 1 at 75% and another at 100% effort, with 2 minutes of recovery between each sprint. Following the final warm up sprint, subjects were given 3 minutes of light active recovery (walking) before the testing protocol began.

Subjects were instructed to stand on the jump plate and perform three no-arm-swing (NAS) countermovement jumps (CMJs) to the best of their ability. If jump height continued to increase, further jumps were conducted until results plateaued. After the final jump, the subject was given 60 seconds to walk to the starting line before they began the repeated sprints. The RSE protocol consisted of performing 12, 30 meter sprints with 30 seconds of active (walking) recovery between sets. Subjects performed sprints until proctol completion or volitional fatigue, whichever occurred first. Subjects were instructed to sprint maximally for the 30 meter stretch, running through the end gate. Subjects were instructed not to jog during their active recovery, which was used to return to the start line. The 30 seconds of elapsed recovery time was tracked on a hand held stopwatch, with an instructor informing the subject when they had 5 seconds remaining and instructing them by saying “set” and “go” at 29 and 30 seconds respectively. This was repeated 12 times, with subjects receiving verbal encouragement throughout the procedure. The subject then repeated 3 CMJs on the jump mat, starting 30 seconds after the end of the final sprint. Subjects were then given 10 minutes of very light active recovery (standing or walking) before conducting 3 more CMJs on the jump mat.

Data Analysis and Statistics

A one way ANOVA evaluated the change in impulse and PPO from pre x post x post 10 of the averages of all subjects. A Tukey's honest significance difference test evaluated the statistical significance between the difference of the different times (pre x post, post x post 10, pre x post 10). A percent fatigue decrement formula was used to calculate invldial percent decrement and average percent decrement using formula 4 from Glaister et al. 2008. An alpha level of 0.05 was used to determine statistical significance.

Results

Table 1. The number sprint and the corresponding time it took to complete for each subject and the percent fatigue decrement score (% FD) for each subject. Average percent fatigue decrement was 6.71%.

	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7
1	5.015	5.494	5.427	4.397	5.423	5.213	5.526
2	5.049	5.793	5.643	4.407	5.572	5.415	5.769
3	5.131	5.962	5.736	4.546	5.88	5.184	5.69
4	5.122	5.988	5.823	4.556	5.959	5.192	5.754
5	5.084	5.969	5.81	4.729	6.15	5.163	5.838
6	5.049	5.864	5.815	4.635	6.055	5.353	5.788
7	5.147	5.882	5.816	4.733	6.337	5.276	5.902
8	5.167	5.908	5.747	4.851	6.084	5.266	5.866
9	5.135	5.899	5.867	4.783	6.438	5.38	5.931
10	5.154	5.961	5.641	4.802	6.792	5.213	5.932
11	5.149	5.944	5.837	4.854	6.615	5.182	5.945
12	5.147	5.858	5.711	4.777	5.987	5.31	5.769
% FD	1.943	6.968	5.757	6.266	12.625	1.922	5.124

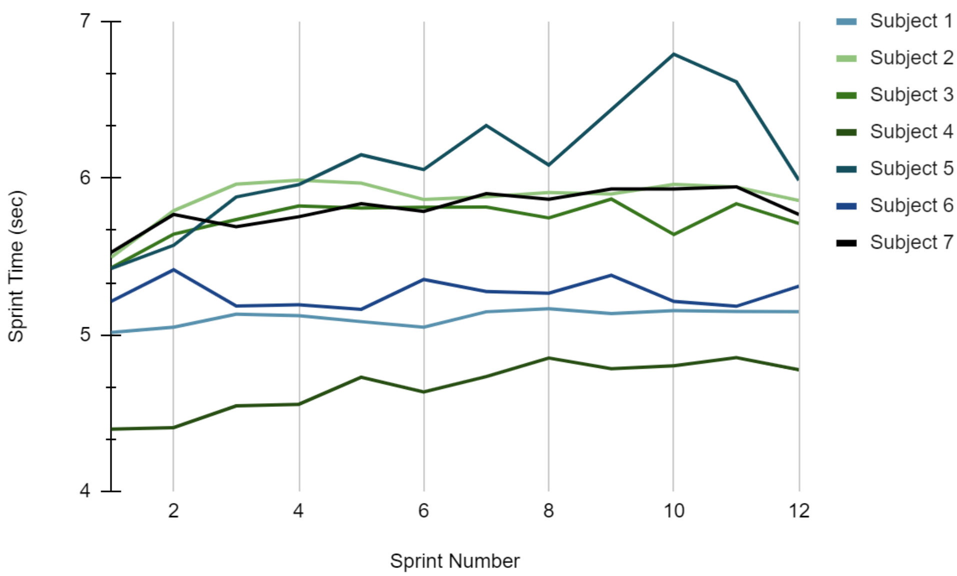

Figure 1. Change in sprint time over the RSE test. Subject 1 was a detrained female, subjects 2-4 female soccer athletes, subjects 5-7 endurance and strength trained males. Average fatigue decrement was 6.71%.

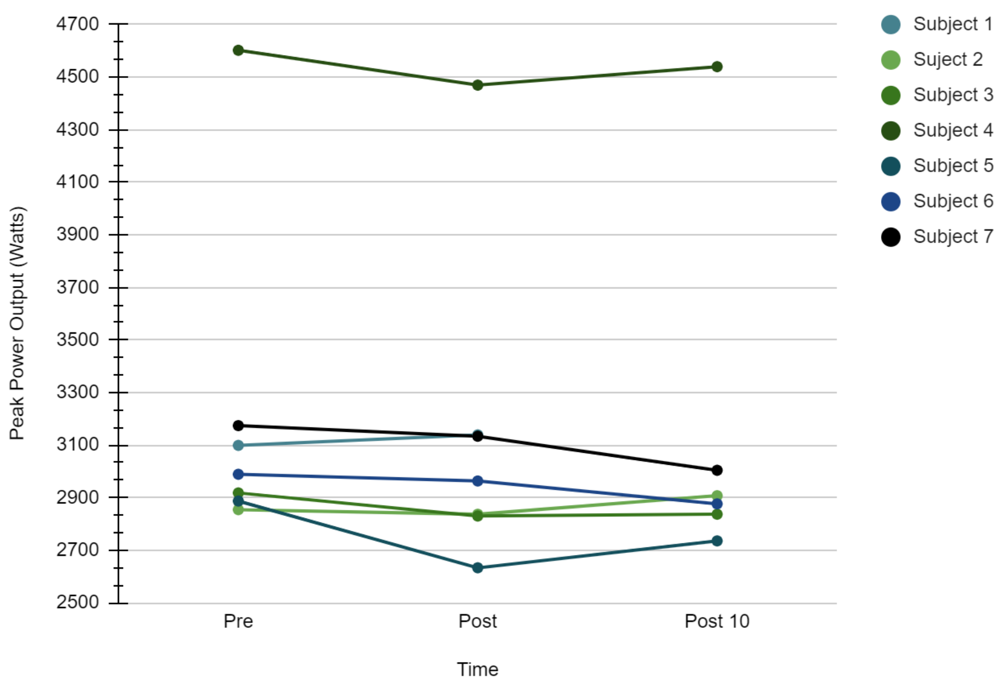

Figure 2. The change in PPO throughout the testing session, characterized by decline in the post jumps. No statistically significant change occurred between the different jump sessions.

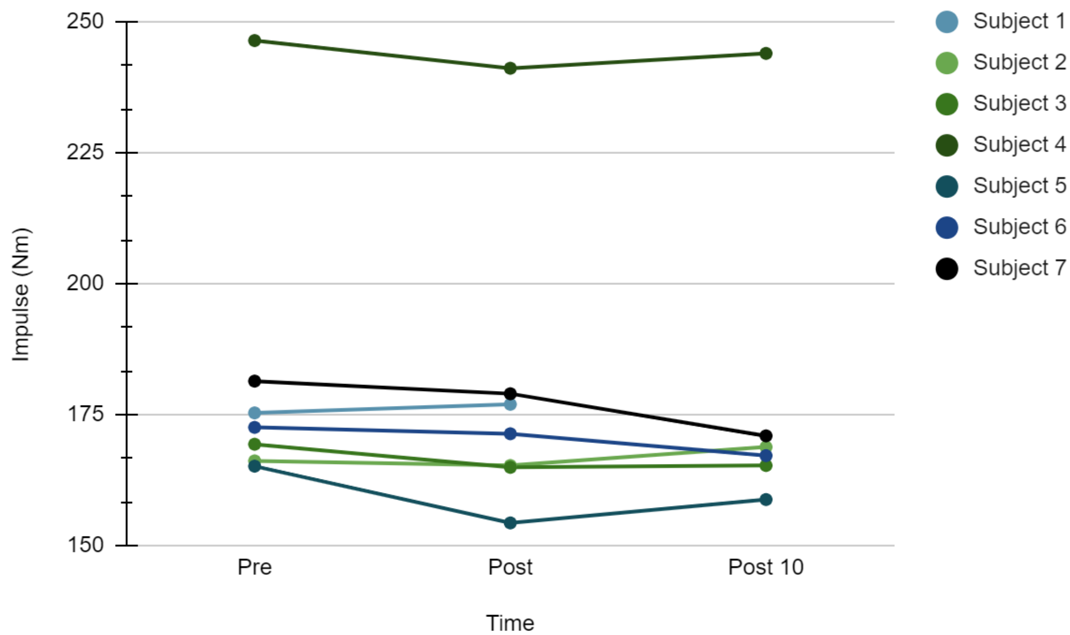

Figure 3. The change in impulse throughout the testing session, characterized by a decline in the post jumps. No statistically significant change occurred between the different jump sessions.

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Discussion

- Decreased impulse and PPO during immediate post jump suggests that athletes are needing more time and effort to give maximal jump following RSE
- We were unable to achieve an average of 12% fatigue decrement as other studies had, we focused on D1 athletes which limited muscle fatigue

References:

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