Vibration May Reduce Negative Impacts of Exercise-Induced Fatigue on Spinal Excitability

Vibrasyon, Egzersizin Spinal Uyarılma Üzerinde Oluşturduğu Yorgunluk Etkilerini Azaltabilir

M. İsmet TOK,[a]
Dianne E. FOWLER,[b]
Muzaffer ÇOLAKOĞLU,[b]
Fikret BADEMKIRAN,[c]
Zafer ÇOLAKOĞLU[c]

[a]Dokuz Eylül University,
School of Sport Science and Technology,
[b]Ege University,
School of Physical Education and Sports,
[c]Department of Neurology,
Ege University Faculty of Medicine,
İzmir

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Yazışma Adresi/*Correspondence:*
Dianne E. FOWLER
Ege University
School of Physical Education and Sports,
İzmir,
TÜRKİYE/TURKEY
difri58@gmail.com

ABSTRACT Objective: The study aimed to investigate the effects of vibration on spinal excitability responses to resistance exercises by examining silent period time variations. **Material and Methods:** 22 male, healthy and physically-active college students (age range 19-28 years) volunteered to participate in the study. Peripheral silent periods of participants were recorded with bipolar surface electrodes fixed over the area of the flexor digitorum sublimis muscle in both upper extremities while applying 30% maximal isometric hand grip strength to the dominant hand: 1) at rest, 2) after 15 standing biceps curls (dominant arm) using 7.6 kg vibration dumbbells without vibration and 3) after 15 standing biceps curls (dominant arm) with the same vibration dumbells with vibration (27 Hz, 2 mm amplitude, 4 mm displacement). Friedman and Wilxocon tests were used to analyse variations in silent periods. **Results:** Exercise alone, without vibration, was found to significantly lengthen the silent period in the non-dominant arm only (p<0.01). Exercise with vibration, however, significantly shortened silent periods bilaterally, when compared with rest and exercise without vibration values (p<0.01), showing that vibration added to exercise eliminates the fatiguing effects of exercise. **Conclusion:** Vibration may counterbalance diminished spinal excitability resulting from exercise-induced fatigue and improves spinal excitability and neurological efficacy.

Key Words: Vibration exercise; Silent period; Spinal excitability

ÖZET Amaç: Bu çalışmada, vibrasyonun direnç egzersizine yanıt olarak meydana gelen spinal uyarılabilirlik değişimleri üzerine etkilerinin sessiz periyot süreleri incelenerek araştırılması amaçlandı. **Gereç ve Yöntemler:** Yaşları 19-28 arasında değişen, sağlıklı ve fiziksel olarak aktif 22 erkek öğrenci çalışmaya gönüllü olarak katıldı. Katılımcıların sessiz periyotları dominant elleri ile maksimum kuvvetlerinin %30 kadar bir pençe kuvveti uygularken her iki üst ekstremitelerinin flexor digitorum sublimis kası üzerine yerleştirilen bipolar yüzeysel elektrotlar ile 1) istirahatte, 2) dominant kolda 7.6 kg vibrasyon dambılı ile vibrasyon uygulamadan ayakta 15 kez biceps curl uyguladıktan sonra, 3) dominant kolda aynı vibrasyon dambılı ile 27 Hz frekans ve 2 mm yer değiştirme amplitütlü vibrasyon uygulayarak, ayakta 15 kez biceps curl uyguladıktan sonra kaydedildi. Sessiz periyottaki değişimleri incelemek amacıyla Friedman ve Wilcoxon testleri kullanıldı. **Bulgular:** Egzersizin istirahat sessiz periyot değerini hem dominant hem de non-dominant tarafta arttırdığı fakat bu artışın sadece non-dominant tarafta anlamlı olduğu gözlendi (p<0.01). Vibrasyonla birlikte egzersiz uygulaması ise, egzersizin tek başına neden olduğu yorgunluk etkisini (sessiz periyot süresi uzaması) her iki tarafta da ortadan kaldırarak sessiz periyot süresini kısalttığı (p<0.01) saptandı. **Sonuç:** Vibrasyon, egzersizle artan yorgunluğun sessiz periyodu uzatıcı etkisini ortadan kaldırarak spinal uyarılabilirliği ve nörolojik etkinliği arttırabilir.

Anahtar Kelimeler: Vibrasyon egzersiz; sessiz periyot; spinal uyarılabilirliği

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When supramaximal stimulation activates a contracting muscle, an M wave is recorded on the electromyography (EMG) tracing. Immediately after the M wave, a period of electrical inactivity lasting nearly 100 msec intervenes before the return of regular EMG activity. This period is referred as the silent period (SP) (Figure 1), and may stem from a halt in firing of muscle spindles[1,15,21,24] or it may be a part of electrical activity, which arises directly from stimulated neurons.[11,17,20,31,36] The SP may result from the activation of fibers appearing after the stimulation of mixed neurons like cutaneous or Ib fibers of homonymous muscles.[14,16,32,36] The lengthening of the SP is a sensitive sign of neuromuscular fatigue and is controlled by afferent proprioceptors.[8]

Vibration causes minor changes in muscle length[4] and high frequency stimulation of Ia afferents causing neurotransmitter release, which in turn helps recruit extra motor units to facilitate neuromuscular function.[28] Vibration may also increase excitability of the α-motor neuron pool (spinal excitability).[23] Vibration exercise is thought by some to generate effects on muscular performance similar to those of weight training.[4] We postulated that vibration may facilitate spinal excitability on exercising muscles, thus we recorded the silent periods from the flexor digitorum sublimis muscle at rest, after exercise and after vibration exercise in both upper extremities.

This study aimed to look at the effects of upper body vibration exercise on the lengthening or shortening of the peripheral silent period to determine if vibration induced neural excitability might decrease the negative impact of exercise-induced fatigue. No literature to date has reported use of sport specific piece of upper body equipment to examine the effects of vibration with exercise. Using a well-calibrated, handheld vibration dumbbell researchers in this study were able to analyze neurological changes in the hopes that the findings would provide beneficial knowledge for exercise physiologists, trainers and researchers in the future.

MATERIALS AND METHODS

The study protocol was approved by the Ethics Committee of the Ege University Medical Faculty. Twenty-two physically-active male college students (age range 19-28 years) gave written, signed consent to participate in the study. First, maximal hand-grip strength was recorded bilaterally while the subject was in the supine position with a grip strength dynamometer (Model 5101®, 5-100 kgf, Takei Kiki Kogyo Co. Ltd., Tokyo, Japan). Then, peripheral SPs of participants were recorded with a Nicolet Viking 4D electromyography device over the flexor digitorum sublimis muscle by bipolar surface electrodes (Medelec large LBS, Ref: 16893T; Oxford Instruments Medical, Old Woking, UK) in both extremities while applying a 30% maximal hand-grip contraction in the dominant hand. EMG recordings were taken under the following conditions: 1) at rest, 2) after 15 biceps curls (while standing) using a 7,6 kg vibration dumbbell (Mini-Vibra Flex Plus®, Orthometrix, Inc., White Plains, USA) (Picture 1) without vibration and, 3) after 15 biceps curls with the same vibration dumbbell with vibration (27 Hz; 2 mm amplitude and 4 mm displacement). Recordings were made with a sweep time of 200 ms, stimulus duration 0.2 ms, and stimulus intensity of 50 mA (bandpass filter, 20 Hz-5 kHz). The mean value of three peripheral SP recordings was calculated and used for statistical analysis.

PICTURE 1: Vibration dumbbell (Mini-Vibra Flex Plus®, Orthometrix, Inc., White Plains, USA).

Variations in SP between groups were analyzed with Friedman and Wilxocon tests using SPSS for Windows® (SSPS Inc., Chicago, USA). Values of $p< 0.05$ and $p< 0.01$ were accepted as statistically significant.

RESULTS

Demographics of the participants are shown in Table 1. The silent periods of dominant (exercised)

TABLE 1: Demographic features of participants (n: 22)

	Mean ± SD	Range (min-max)
Age (years)	21,7 ± 2,26	19-28
Height (cms)	177,5 ± 6,79	163-191
Weight (kgs)	70,1 ± 7,60	55-86

and non-dominant (non-exercised) extremities at rest were not significantly different (p> 0.05; Table 2). After exercise SPs lengthened in both the dominant (exercised) and non-dominant arms, however this was statistically significant only for the non-dominant arm (p< 0.01; Figure 1 and Table 2). Vibration with exercise, on the other hand, resulted in shortened SPs in both arms in relation to rest and exercise without vibration values (p< 0.01; Figure 2, Table 2).

DISCUSSION

Our results show exercise alone may lengthen SPs in both exercising and non-exercising extremities while exercise with vibration acts to shorten the SPs in both of these limbs. Therefore, the addition of vibration may facilitate excitatory functions of exercising muscles.

Findings that SP duration increases with exercise are supported by previous studies. Since increases in extra-cellular potassium and other

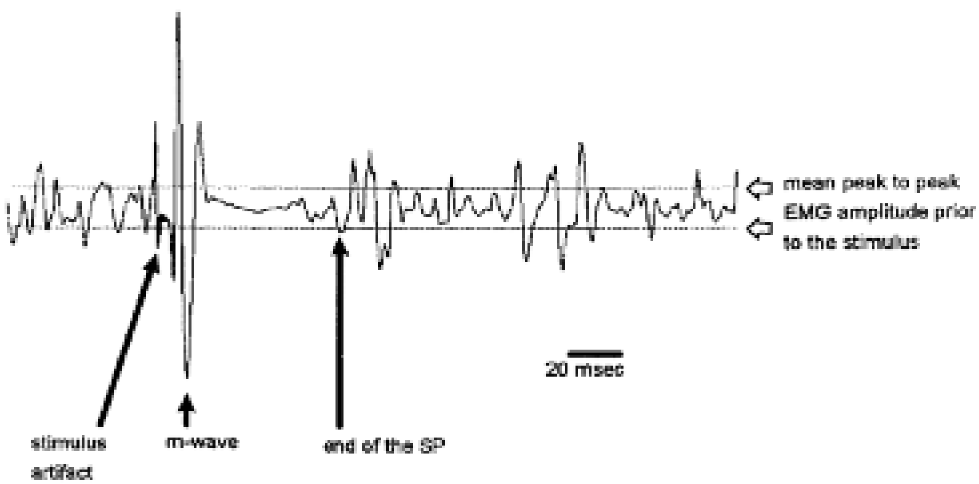

FIGURE 1: Silent Period EMG recording.

TABLE 2: Differences between peripheral silent periods (milliseconds) in dominant and non-dominant upper extremities, pre-exercise (rest), post-exercise (Ex) and post-vibration exercise (VibEx).

	Dominant Side (Exercised)			Non-Dominant Side (Non-ex)		
	Rest	Ex	VibEx	Rest	Ex	VibEx
Silent Period (msec)	42.6±12.6	46.7±8.4	33.2±9.1	40.6±9.6	50.3±10.2	33.4±13.2
Friedman	x^2 = 20.74 p = 0.0001**			x^2 = 21.91 p = 0.0001*		
		Ex	VibEx		Ex	VibEx
Wilcoxon	Rest	0.115	0.0001**	Rest	0.010**	0.003**
(p values)	Ex	—	0.0001**	Ex	—	0.001**
Bialateral Differences (Dominant vs. Non-Dominant)						
Wilcoxon	Rest		Ex		VibEx	
(p values)	0.257		0.168		0.896	

*: p<0.05; **:p<0.01.

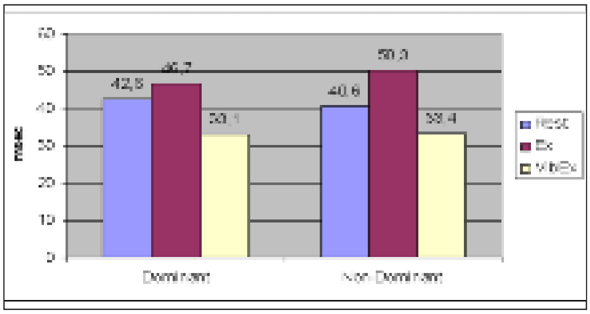

FIGURE 2: Silent period variations in dominant and non-dominant upper extremities, pre-exercise (rest), post-exercise (Ex) and post-vibration exercise (VibEx).

metabolites cause reflexive α-motor neuron pool inhibition, firing rates diminish.[29,33,34] During fatigue, central and afferent activities are affected, motor units are weakened and central stimulations are needed to supplement additional motor units. SP times are related to central stimulus rates that reach the α-motor neuron pool and to inhibition of cutaneous afferents that innervates neuron pool.[18,32,36] SP extends with any activation of fatiguing muscle. With recovery from fatigue, blood flow reduces metabolites rapidly and homeostasis occurs.[2] However, additional central stimulation is still needed for force production in muscles. In the relaxation period, after contraction, more motor units have to be recruited to sustain force production needed for muscle contraction. In this period, inhibitory afferent feedback compensation mechanisms are not required. Therefore, since inhibitory afferent feedback mechanism effects are diminished but increased central stimulation continues, SPs are shortened when compared with prefatigued values.

Cox and colleagues found that subjects' silent period times were decreased for 10 minutes after maximum voluntary contraction of the vastus lateralis muscles as compared to silent period values at rest.[8] The length of the silent period SP reflects spinal excitability and sensitivity levels. Increased spinal excitability is suggested by shortened SPs; silent periods are sensitive to neuromuscular changes caused by fatigue and it is thought that these are modified by sensory afferent fiber stimulation.[8]

Mechanical vibration increases neurological excitability in muscles.[35] This is known as the tonic vibration reflex (TVR).[27] TVR results from the stretching of muscle spindles, activating Ia afferent neural signals, which in turn activate alpha-motor neurons and lead to muscle fiber contraction. TVR activates motor units via polysynaptic pathways. TVR increased motor unit recruitment resulting from muscle spindle and polysynaptic pathways activation.[11] In effect, muscle activation is temporarily increased. But, EMG activity shows that muscle spindles stimulated for a lengthened period of time by vibration will lead to fatigue as evidenced by decreased motor unit firing and decreased contraction strength.[10,11] In contrast, use of vibration to stimulate muscles in lower extremities resulted in increased power and strength as well as improvements in body balance thought to be due to neurological adaptations.[2]

Several authors have found potentiation of neural pathways by total body vibration when testing resistance and explosive training techniques.[9] Resistance training is known to affect corticospinal cells and neuronal transmission in spinal motor neurons.[6,7] During vibration, proprioceptive pathways and sensory receptors are activated and reflex muscle contractions occur. After a twelve-week exercise program, isometric strength increases, in large part through the positive proprioceptive effects of the feedback loop.[9] Along with stimulation of the sensory receptors, the stretch reflex is activated; as the tonic vibration reflex is activated, sensitivity of the muscle spindles increases, thus causing an overall increase in activation of the motor-neuron pool.[36]

After vibration exercises, the EMG-power is seen to decrease, which is seen as a sign of increasing the neural activity of the neuromuscular system, whereas EMG-rms values increased 200%.[5] The decrease in the EMG/power ratio with vibration means that vibration increases neuromuscular activity. With whole body vibration, the impulses increase to the IA fibers and after voluntary contractions the commands coming to the motor-neuron pool increase, as well as the H reflex/M response. These effects reveal the ability of the α-motor-neurons to be stimulated otherwise known as up-regulation.[23]

In our study, exercise and vibration exercise were applied in the dominant extremity only, and whereas exercise alone lengthened the silent period in the dominant extremity, exercise with vibration shortened the silent period in both dominant (exercised) and non-dominant (non-exercised) extremities. Silent periods shortened significantly in both extremities after exercise compared with SP changes after rest and after exercise only, suggesting that vibration may help reduce the fatiguing effects of exercise. It is also interesting to note this crossover effect may have positive implications for training uninjured limb and seeing a beneficial effect on the injured limb.

Although new literature[3,22,25] suggests that bench press and biceps curl maximal strength gains are not evident immediately after vibration exercise application, this is not necessarily inconsistent with our findings. Our results suggest that vibration exercise does improve neural excitability and may improve strength gains over time if vibration is included in the exercise routine. Further research is required to clarify these issues.

In conclusion, exercise with vibration dumbbells seem to be effective to facilitate strength and power gains. Further studies might focus on chronic effects of vibration trainings, duration of recovery from acute effects, optimal loading duration for a single repetition of a vibration exercise and the inclusion of other cohort groups that might benefit from this unique training.

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