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RESEARCH ARTICLE

Assessment of onset of the duration of fatigue in muscle using surface electromyography on women during the different phases of menstrual cycle

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ABSTRACT

Background: Menstrual cycle is a major biological process for women during their reproductive years. Female sex hormones (estrogen and progesterone) fluctuate radically throughout the menstrual cycle. In women, there is a strong link between these fluctuating levels of hormones and their influence on muscle performance throughout the menstrual cycle. Estrogen has a beneficial effect on muscle efficiency. The decrease in muscle strength and early fatigability in muscle coincides with decrease in estrogen in females during certain periods of menstrual cycle, indicating the need for special care to avoid injuries during those periods. In the present study, the duration of the onset of muscle fatigue was assessed and compared to study the muscle performance during the four different phases of menstrual cycle in females of 18–25 years for 3 consecutive months. **Aims and Objectives:** This study aims to assess the duration of the onset of muscle fatigue (seconds) using surface electromyography and to compare the duration of the onset of muscle fatigue during four different phases of menstrual cycle for 3 consecutive months. **Materials and Methods:** Fifty apparently healthy female subjects selected for the study. Duration of the onset of fatigue in muscle was assessed on the following days of the menstrual cycle for 3 consecutive months: F1 phase (2nd day), F2 phase (12th day), L1 phase (20th day), and L2 phase (26th day). LH kit (luteinizing hormone (LH)-ovulation predictor) was used to confirm for the occurrence of ovulation during that particular menstrual month. Onset of the duration of fatigue was recorded using surface EMG on the right/left biceps muscle out. A total of six comparisons were made between F1 and F2, F1 and L1, F1 and L2, F2 and L1, F2 and L2, and L1 and L2. Student's *t*-test (two tailed, dependent) has been used to find the significance of study parameters on continuous scale within each phase of menstrual cycle. **Results:** Onset of the duration of fatigue (seconds) significantly occurred late during the F2 (71.68 ± 15.61, 70.26 ± 14.68, and 68.06 ± 12.79) followed by L1 phase (59.02 ± 12.92, 59.22 ± 11.49, and 62.02 ± 11.05) and the onset of fatigue significantly occurred early during L2 (42.02 ± 8.81, 39.24 ± 8.83, and 39.42 ± 6.66) and F1 phases (37.58 ± 9.21, 37.26 ± 8.64, and 35.70 ± 5.86) of all the 3 months with $P < 0.001$. **Conclusions:** Muscle performance was highest with duration of the onset of fatigue occurring late in muscle during F2 phase of menstrual cycle which corresponds with estrogen peak during ovulation, followed by L2 phase wherein there is another estrogen peak after ovulation during early luteal phase. The muscle performance declined as fatigue occurred very early during F1 and L2 phase of menstrual cycle as the estrogen levels decline accordingly. Estrogen has a positive effect on muscle tissue, with its two peaks occurring in its concentration levels during the pre-ovulatory and post-ovulatory (midluteal) phase of menstrual cycle and decline in muscle efficiency with drop in its concentration levels during the menses and premenstrual phase.

KEY WORDS: Menstrual Cycle; Duration of Onset of Fatigue in Muscle; Surface Electromyography; Estrogen

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INTRODUCTION

In the present era, the role of women across the world in different spheres has significantly expanded from what they were traditionally in the past. In females, menstrual cycle is a major biological process during their reproductive years.

Menstrual cycle is associated with fluctuations in female sex hormones (estrogen and progesterone) through the normal 28–30 days cycle. Hormonal fluctuations during the course of a women's menstrual cycle, apart from reproductive system also affect the physiological and psychological component of the body, which has an influence on her day-to-day performance.[1-3]

In women, there exists a strong link between these fluctuating hormones and muscle strength and fatigability.[4] The female sex steroid hormone, estrogen has a beneficial effect on muscle performance.[5,6] With the rising participation of females in athletics and physically demanding occupations has led to the interest in understanding the biology of menstrual cycle along with which the importance of female sex hormones for maintaining the health and well-being of skeletal muscle has also been recognized.[7]

Consequently, the hormonal variations may lead to either improved or declined muscle performance at different times of menstrual cycle.[8] Few studies have also demonstrated that increased muscle fatigue levels may be associated with injuries in female athletes.[9-11]

In the late 19th century, with the rising participation of females in athletics and physically demanding occupations has led to the interest in understanding the biology of menstrual cycle along with which the importance of female sex hormones for maintaining the health and well-being of skeletal muscle has also been recognized.[6,7] There has been an increase in scientific research, involving studies focusing on women's health and their athletic performance.[2]

Muscle fatigue is the decline in ability of a muscle to generate force. It is the reduction in maximum voluntary force with failure to maintain the required/expected amount of force.[12,13]

Measurement of muscular fatigue is typically determined as the change in maximum voluntary contraction (MVC) force over repeated or sustained contractions. Muscle fatigue is generally defined as a decrease in or inability to sustain the maximum force-generating capacity of the muscle.[14]

Most of the studies have been carried out to assess the effect of fluctuating hormones on muscle performance during menstrual cycle in female athletes, with very few studies done on non-athletic eumennorheic women.

The present study has been carried out on females in the age group of 18–25 years having a normal 28–30 days regular menstrual cycle, to evaluate the effect of hormonal variations on muscle fatigability during the different phases of menstrual cycle for 3 consecutive months.

This study will help to create awareness among the sports coaches for women, clinicians, and researchers, about the physiological changes occurring with variations in sex hormones and its influence on muscle efficiency during the menstrual cycle. It would be helpful in serial maintenance of the records of their performance throughout the menstrual cycle and to bring about modifications in training schedule of various sports for female athletes and also in other occupational workplaces, so as to achieve the best performance in them and reduce the risk of injuries.

Hypothesis: Muscle performance in women varies across the menstrual cycle.

MATERIALS AND METHODS

This is a descriptive study, in which the duration of the onset of fatigue in the muscle was measured in females in the age group of 18–25 years. Fifty apparently healthy female subjects selected for the study. Ethical clearance was obtained from the Institutional Ethical Committee for Human Research of Sri Siddhartha Medical College, Tumkur. Source of data: Young healthy females, studying in, Sri Siddhartha Medical College, Tumkur, were chosen for the study.

Inclusion Criteria

Young apparently healthy females in the age group of 18–25 years were included in the study. Females having a normal regular menstrual cycle of about 28–30 days every month were included in the study.

Exclusion Criteria

Females with irregular menstrual cycle, females with muscular and neurological disorders, and females on long-term use of drugs influencing menstrual cycle were excluded from the study.

Subjects who satisfy the inclusion criteria were selected for the study. Subjects were familiarized with laboratory environment and the protocol was explained. Written informed consent was obtained. All the subjects were examined for general physical examination and routine bedside clinical examination to rule out any abnormality.

Procedure

The subjects were informed about the procedure and written consent was obtained from the subjects. Detailed menstrual history was taken, the various phases were divided into four different phases and the study parameters were assessed during the following days of menstrual cycle of 28–30 days.

Duration of the onset of fatigue in muscle was assessed on the following days of the menstrual cycle for 3 consecutive months: F1 phase (2nd day), F2 phase (12th day), L1 phase (20th day), and L2 phase (26th day).

LH-ovulation predictor (LH KIT) was used to confirm for occurrence of ovulation. Early morning urine sample was collected on the 12th and 13th days of menstrual cycle for the test; a pink line on the strip was confirmed as positive result for occurrence of ovulation in that particular menstrual cycle (LH ovulation test device, ACU-check. RAPID Diagnostic Test. Mfd by: Acon Biotech Co., Ltd. Lic no. 20020050).

Onset of the duration of fatigue was recorded using surface (S)-EMG was recorded using-RMS ALERON 201 EMG EP MARK-II, ISO 9001:2000 Company.

For recording of the onset of duration muscle fatigue using S-EMG: Right/left biceps muscle was selected for the study. The surface EMG electrodes were placed as follows, reference electrode was placed on the biceps muscle tendon and active (recording) electrode was placed on bulk of the muscle, ground electrode on the dorsum of hand. The subject was asked to perform isometric MVC in the muscle, each contraction was held for approximately 5 s. Three such contractions separated by 2 min of rest between the maneuver were measured, and the highest of the three values obtained by EMG signal analysis was taken as the MVC expressed in %. After 5 min of rest, subject was asked to maintain an isometric voluntary contraction at MVC of 60%, until the subject felt pain and exhausted and was unable to maintain the required 60% MVC further and the onset of the duration of fatigue in the biceps muscle was noted down in seconds.

Comparison of onset of the duration of muscle fatigue during four different phases of menstrual cycle for the 3 months was carried out.

A total of six comparisons were made between F1 and F2, F1 and L1, F1 and L2, F2 and L1, F2 and L2, and L1 and L2.

Statistics Analysis

Descriptive statistical analysis has been carried out in the present study. Results on continuous measurements are presented on mean ± standard division (Min-Max) and results on categorical measurements are presented in number (%). Significance is assessed at 5% level of significance. The following assumptions on data are made. Assumptions: (1) Dependent variables should be normally distributed and (2) samples drawn from the population should be random. Student's *t*-test (two tailed, dependent) has been used to find the significance of the study parameters on continuous scale within each group.

RESULTS

Onset of the duration of fatigue (seconds) significantly occurred late during the F2 (71.68 ± 15.61, 70.26 ± 14.68, and 68.06 ± 12.79) followed by L1 phase (59.02 ± 12.92, 59.22 ± 11.49, and 62.02 ± 11.05) and the onset of fatigue significantly occurred early during L2 (42.02 ± 8.81, 39.24 ± 8.83, and 39.42 ± 6.66) and F1 phases (37.58 ± 9.21, 37.26 ± 8.64, and 35.70 ± 5.86) of all the 3 months with $P < 0.001$ [Tables 1 and 2].

DISCUSSION

In the present study conducted on females ,the duration of onset of muscle fatigue was estimated for three consecutive months. Each menstrual cycle divided into four different phases. The four different phases of menstrual cycle were divided as F1 (menses), F2 (pre-ovulatory), L1 (post-ovulatory), and L2 (premenstrual). Significant late occurrence of fatigue in the muscle was found during the F2

Table 1: Onset of duration in different phases of menstrual cycle for 3 consecutive months

Phase of menstrual cycle	Month 1	Month 2	Month 3
F1	37.58±9.21	37.26±8.64	35.70±5.86
F2	71.68±15.61	70.26±14.68	68.06±12.79
L1	59.02±12.92	59.22±11.49	62.02±11.05
L2	42.02±8.81	39.24±8.83	39.42±6.66

Table 2: Comparison of onset of duration of muscle fatigue during different phases of menstrual cycle

Study variables	Phase	Month 1	Month 2	Month 3
Onset of fatigue (seconds)	F1	37.58±9.21	37.26±8.64	35.70±5.86
	F2	71.68±15.61	70.26±14.68	68.06±12.79
	P	<0.001**	<0.001**	<0.001**
	F1	37.58±9.21	37.26±8.64	35.70±5.86
	L1	59.02±12.92	59.22±11.49	62.02±11.05
	P	<0.001**	<0.001**	<0.001**
	F1	37.58±9.21	37.26±8.64	35.70±5.86
	L2	42.02±8.81	39.24±8.83	39.42±6.66
	P	0.006**	0.060+	0.001**
	F2	71.68±15.61	70.26±14.68	68.06±12.79
	L1	59.02±12.92	59.22±11.49	62.02±11.05
	P	<0.001**	<0.001**	<0.001**
	F2	71.68±15.61	70.26±14.68	68.06±12.79
	L2	42.02±8.81	39.24±8.83	39.42±6.66
	P	<0.001**	<0.001**	<0.001**
	L1	59.02±12.92	59.22±11.49	62.02±11.05
	L2	42.02±8.81	39.24±8.83	39.42±6.66
	P	<0.001**	<0.001**	<0.001**

P <0.05 is considered to be significant, ** P<0.001 considered to be highly significant, + P=0.06 significant

and L1 phases when compared to F1 and L2 phase during which with early occurrence of fatigue. In the present study, fatigue was measured by reduction in MVC, with failure to maintain the required amount of force. The onset of fatigue occurred significantly early during F1 (menses) – 37 s and L2 (premenstrual) – 42 s phases when compared to the other two phases F2 – 71 s and L1 phase – 59 s.

Studies conducted on female athletes showed similar results, higher injury rates have been observed during the premenstrual and menstrual phase with decrease in the estrogen levels in body.[15,16] Hewitt, Karageanes *et al.*, Myklebust *et al.*, and Wojtys *et al.* have reported that, in females, muscle injury is most common during the late luteal and menstruation phases of the cycle due to less estrogen levels in the body.[3,15,17-19]

It was demonstrated that estrogen has been shown to protect the younger women from muscle injury apparently by stabilizing the muscle membrane and hence possibly minimizing post-exercise muscle damage and soreness.[6,20]

Moller-Nielson and Hammar reported that athletes taking hormonal contraceptives had a lower injury rate because the elevated estrogen levels in oral contraceptive pills (OCP) throughout the menstrual cycle when compared to athletes not on OCP use.[16]

Various studies done on female athletes, to assess their sports performance during the various phases of menstrual cycle, reported that the better performance was observed during the pre-ovulatory and post-ovulatory phases. Their performance was low during the menstruation and premenstrual phases when there is decrease in the estrogen levels in the body.[2,21,22,23]

Estrogen has a positive effect on muscle tissue, with its two peaks occurring in its concentration levels during the pre-ovulatory and post-ovulatory (midluteal) phase of menstrual cycle and decline in muscle efficiency with drop in its concentration levels during the menses and premenstrual phase.[8,24]

One more finding was observed in the present study, the muscle performance in F2 (premenstrual phase) was significantly high when compared with L1 phase (post-ovulatory phase). The explanation for the above finding could be due to the level of estrogen is relatively more, during its first major peak occurring in pre-ovulatory phase, followed by a second, lesser peak in estrogen concentrations occurring during post-ovulatory phase.

Skeleton muscle cell has the estrogen receptor on its cell membrane, in the cytoplasm and on the nuclear membrane.[25-28]

Estrogen exerts it direct effect on skeletal muscle through ER, which has a beneficial effect on muscle tissue, and fluctuations in levels of estrogen in the body throughout the menstrual cycle play a role in dynamic muscle control.[3,6,29,30]

Studies done on mice speculate the molecular mechanism of estrogen on skeletal muscle, by improving the reduction-oxidation state in muscle fibers and thus keeping muscle proteins myosin free from post-translational oxidative modifications, could contribute to the maintenance of protein structure-function and ultimately maintain strength.[5,31]

Limitation of the study was very less sample size of the subjects as follow-up of the subjects for recording of the onset of muscle fatigue for 3 consecutive months for 4 recordings per month was difficult.

CONCLUSIONS

From the results obtained in the present study, it shows that the muscle performance in women during the F2 and L1 phases of menstrual cycle was enhanced showing late occurrence of fatigue in muscle when compared to F1 and L2 phases wherein there was significant early onset of fatigue. This was due to estrogen peak occurring during F2 (pre-ovulatory) and L1 (post-ovulatory) phase and decline in estrogen levels during F1 (menses) and L2 (premenstrual) phases of menstrual cycle. Estrogen has a beneficial action on skeletal muscle; it acts through its receptors estrogen response (ER) α and β. The ER responsiveness differs with the circulating levels of estrogen concentrations in the body during the menstrual cycle. Having quantified the data, based on onset of muscle fatigue in the present study, it would create a guideline for the clinicians, researchers, and sport coaches for female athletes to consider the influence of hormonal variations on muscle performance, and framing the training schedules for female athletes and modify the working schedules for women involved in physical work. This would aid in prevention of injuries and to achieve the optimal performance in them. Hence, it can be concluded that there exists a relationship between estrogen and muscle performance in women.

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