ABDOMINAL AND LOW BACK MUSCLE INVOLVEMENT DURING EIGHT SIT-UP VARIATIONS

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Sit-up exercises are often recommended by health and fitness experts and by members of the medical community as both a prophylactic and a treatment for low back pain. The general rationale for such prescriptions is that an increase in the resting tension levels of the abdominal muscles may help prevent or reduce excessive anterior-tilt of the pelvis and lumbar lordosis. Although a variety of sit-up styles or variations are currently practiced, it is well-documented that at least some variations of the sit-up also exercise the hip-flexor muscles. Among the hip-flexors is the iliopsoas complex, which tends to increase lumbar lordosis when it is over-developed. Since this is undesirable in that excessive lumbar lordosis may actually contribute to the development of low back pain, the optimal sit-up exercise is clearly one which maximizes abdominal muscle involvement while minimizing the participation of the hip flexors. For these reasons, the hook-lying sit-up, (performed with the knees in flexion), has been recommended (Williams, 1974).

An additional consideration for the low back pain patient or the individual with weak low back muscles, however, is the amount of tension required in the low back muscles themselves during the performance of any sort of exercise. Although strengthening the low back muscles may be as much a prophylactic for low back pain as is strengthening the abdominal muscles, this issue is worthy of evaluation for several reasons. Excessive tension or spasming in the low back muscles is frequently a symptom of low back injuries. Intentionally exercising the low back muscles under such conditions would obviously be contraindicated. Another consideration is that in general, increased tension in the paraspinal muscles also tends to increase compression on the intervertebral discs. Of particular concern is a clinical report that the use of sit-up exercises appears to have actually been a causal factor in the development of 19 cases of low back pain (Mutoh, Mori, Nakamura, & Miyashita, 1983).

The following study was consequently undertaken to evaluate the relative requirements of the low back muscles, the abdominal muscles, and the hip flexors during the performances of eight commonly used variations of the sit-up exercise.

Methods

Twenty-seven males aged 20-36 years ($\bar{X}$ = 29±4.7 years) volunteered to participate as subjects in the investigation and signed informed consent documents. For the collection of data, subjects were attired only in tight-fitting stretch swimming suits to facilitate location of joint centers and placement of EMG electrodes.

The experimental protocol consisted of the performance by each subject of three repetitions of each of eight variations of the sit-up, with variations ordered randomly. Sit-up versions included were hook-lying sit-ups with knee angles of 65, 90, and 105 degrees, and the long-lying (0 degree knee angle) sit-up, all performed both with the feet manually supported and with the feet unsupported. Each exercise involved elevation of the trunk from a flat supine position to an approximately vertical position, followed by a return to the supine position. All trials were performed with the subject's arms folded across the chest.

Subjects were familiarized with each sit-up variation during a practice session prior to the collection of data. During both practice and testing sessions, subjects were instructed to maintain a slow, rhythmic movement and to avoid jerking. Movement speed was controlled by a verbal cadence from one of the investigators, with three repetitions of a given sit-up variation taking approximately 15 seconds. At least one minute of rest was provided between trials to minimize any effect of fatigue.

Figure 1 displays the convention used for the measurement of knee angle. Knee angles were established using a large clear plastic goniometer aligned over tape markers fixed laterally over each subject's hip, knee, and ankle joints.

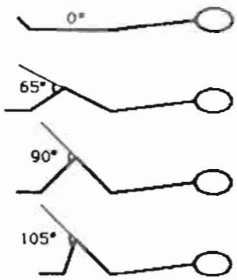

Figure 1 Knee angle designations.

Myoelectric activity during sit-up performances was monitored with 8mm Beckman recessed bipolar surface electrodes positioned at standardized sites over the rectus abdominis, the external obliques, the rectus femoris, and sacrospinalis at the level of the third lumbar vertebra. EMG signals were channeled to an Orion computer, which generated digital and graphical output for the integrated myoelectric signal over the three repetitions of each sit-up variation.

A 4x2 (knee angle x feet support) repeated measures factorial analysis of variance, was conducted for analyzing mean myoelectric activity for each electrode site separately. The criterion level for significant difference was set at $\alpha=0.05$. Tukey's HSD procedure was used to test all appropriate pairwise comparisons for differences associated with knee angle, with the exception of main effects for which the sphericity assumption was violated. For any effect for which sphericity was violated, the Bonferroni comparison method was employed as suggested by Maxwell (1980). Scheffé post hoc comparisons were used to test interaction effects. Tests of sphericity (Anderson, 1958) were performed on both the knee angle main effects and the omnibus tests of interaction to determine whether the sphericity assumption had been violated.

Results and Discussion

Figure 2 displays the patterns of myoelectric activity recorded at all four electrode sites. At both the rectus abdominis and extrenal oblique sites significantly greater amounts of myoelectric activity were present with the feet unsupported than with the feet supported.

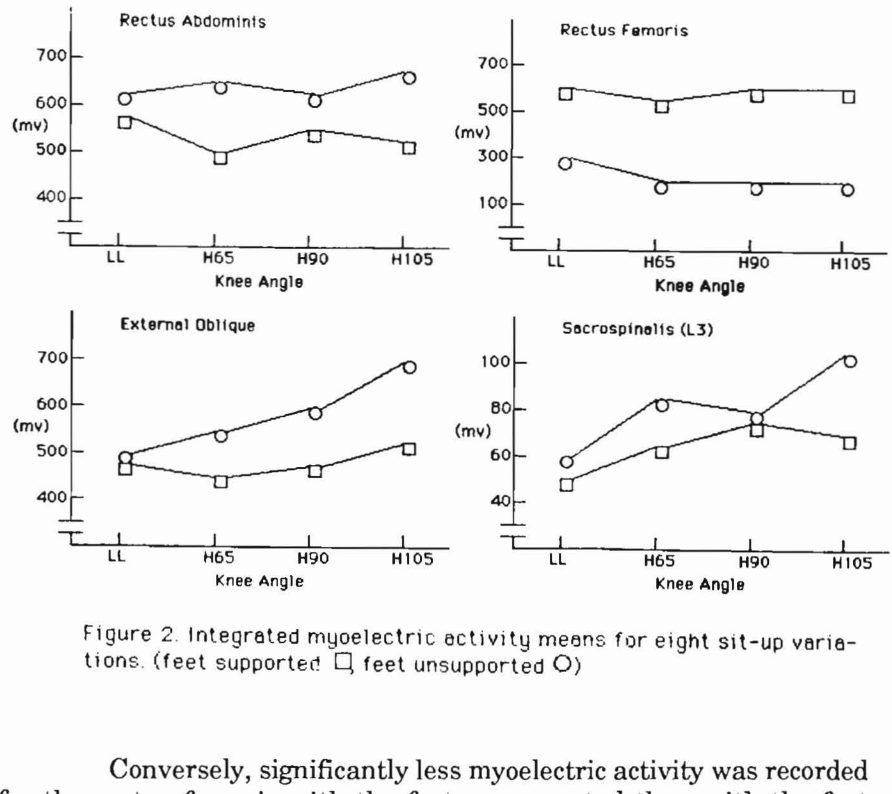

Figure 2. Integrated myoelectric activity means for eight sit-up variations. (feet supported □, feet unsupported ○)

Conversely, significantly less myoelectric activity was recorded for the rectus femoris with the feet unsupported than with the feet supported. This pattern of increased abdominal muscle contribution in the absence of feet support and increased hip flexor muscle contribution when the feet are supported is consistent with the bulk of the findings reported int he literature (De Lacerda, 1978; Flint, 1965b; Godfrey, Kindig, & Windell, 1977; Gutin & Lipetz, 1971; Noble, 1981; Walters & Partridge, 1957).

At the external oblique site a significant F value was also calculated for the knee angle factor. Tukey HSD comparisons indicated more myoelectric activity with the 105 degree knee angle than for either the 65 degree knee angle or long-lying positions. Several other investigators (Godfrey et al., 1977; Gutin & Lipetz, 1971) have also reported greater myoelectric activity in the abdominal muscles during hook-lying sit-ups as opposed to long-lying sit-ups. The theory often cited to explain this phenomenon is that a supine position with hip flexion present produces a reduction in the resting tension present in the iliopsoas complex, thus inhibiting its ability to contribute to the movement. As Kelley (1982) has pointed out, however, a more important consideration is probably that the bent-knee position dramatically reduces the resistance torque produced by the lower extremity at the hip joint, thereby increasing the torque requirement for the upper extremity during the performance of a sit-up. The same pattern of greater myoelectric activity with the 105 degree knee angle position as compared to the long-lying position appeared to be present for the rectus abdominis data, though the F value for knee position was not significant for either the rectus abdominis or the rectus femoris.

A significant interaction between feet support and knee angle factors was also found for myoelectric activity at the external oblique site. Scheffe interaction comparisons showed the difference between feet support and non-support conditions for the long-lying sit-ups to be significantly smaller than the difference between the feet support and non-support conditions at the 105 degree angle position. As shown in Figure 2, the effect of the feet support condition tended to increase with increasing knee angle at the external oblique site.

For myoelectric activity at the sacrospinalis site, significant differences among means were found for both feet support and knee angle. Greater myoelectric activity was present when the feet were unsupported as compared to supported. The Bonferroni test also showed significantly greater myoelectric activity present in all of the hook-lying positions than in the long-lying position. These results indicate that although the sacrospinalis does not contribute directly to the performance of a sit-up, the style of sit-up which is executed affects the myoelectric activity, and presumably the tension level, present in the lumbar region of the muscle.

The increase in lumbar myoelectric activity observed in the absence of feet support may reflect an increase in muscle tension generated to help stabilize the spine in the presence of the significantly increased abdominal muscle tension required to perform that type of sit-up exercise. The same reasoning would apply to the increased myoelectric activity at both the external oblique and sacrospinalis sites during execution of hook-lying as opposed to long-lying sit-ups.

Another factor of potential influence is the relative amount of stretch present in the lumbar region of sacrospinalis prior to initiation of the sit-up. The orientation of the pelvis, which affects the amount of stretch in the lumbar region of sacrospinalis, is influenced by the position of the legs at the beginning of a sit-up. As Soderberg and Cook (1984) have explained, however, the effect of muscle stretch is a decrease in the amount of myoelectric activity generated if other factors are held constant. If the effect of muscle stretch were the determining one, then, a decrease would be expected rather than an increase in lumbar myoelectric activity during hook-lying sit-ups compared to long-lying sit-ups.

Another possible interpretation of the results for the lumbar sacrospinalis relates to the report of Ricci, Marchetti, and Figura (1981) that lumbar "hollowing", or hyperextension, is required prior to the initiation of trunk motion during the performance of a sit-up. Since the lumbar spine tends to be more flattened (less lordotic) when an individual is in a hook-lying position as compared to the long-lying position, the elevated levels of lumbar myoelectric activity observed for the hook-lying positions may be derived, at least partially, from added tension needed to achieve this pre-motion lumbar hyperextension.

In summary, the findings of this investigation reconfirm that the absence of feet support and the hook-lying as opposed to the long-lying position are factors which increase the myoelectric activity, and presumably the tension levels, present in the abdominal muscles during the performance of sit-up exercise. The same two factors also increased the recorded levels of myoelectric activity in the lumbar region of the sacrospinalis. Also documented is an increase in myoelectric activity in the rectus femoris when the feet are supported rather than not supported.

Applications

Since low back pain has become a well-publicized major health problem many health and physical fitness agencies recommend specific exercises designed to reduce the likelihood of an individual's acquiring low back pain. Physical educators and coaches particularly need to be well-informed about exercises which are purported to fit into this category, since such individuals are considered to be accurate sources of this type of information by students and athletes, and by the public in general.

The results of this investigation indicate that among those sit-up versions examined, although the hook-lying sit-up with the feet unsupported is the most taxing to the abdominal muscles, it is also the most taxing to the low back muscles. Although strong low back muscles may be as good a prophylactic for low back pain as strong abdominal muscles, this version of the sit-up should be used very judiciously by individuals with weak low back muscles or with a history of low back pain.

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