COORDINATION OF AXIAL MOVEMENT: INFLUENCE OF SPEED OF THE SIT-UP

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INTRODUCTION

The sit-up is a complex mechanical task that requires the coordination of a multi-link kinematic chain. Successful performance requires the use of proximal and distal, and dorsal and ventral musculature. A previous study decomposed the sit-up into four distinct phases based on the kinematics of the movement (Cordo et al., 2003). Phases 1 and 2 correspond to trunk curling and lumbar lift respectively. The other phases correspond to when the pelvis rotates towards the feet while the feet are not in contact (phase 3), and are in contact (phase 4) with the surface. This current study investigates how these kinematic phases scale with increasing speed of movement. This study also identifies whether the motor command scales to perform the movement at different velocities.

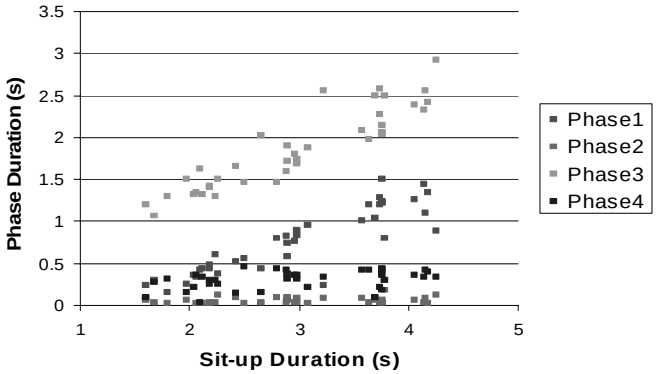
METHODS

Eleven subjects [age: 31.4 (± 7.5) yrs, height: 174 (± 7.2) cm, mass: 70.1 (± 10.6) kg] lay supine on a force table and completed unconstrained sit-ups at self-paced speeds. Feedback was given following each sit-up regarding the duration of the movement together with instructions about the pace of the subsequent sit-up, in order to complete sit-ups across the range of one to four seconds. Kinematic data were collected using a five-camera VICON motion analysis system recording at 50 Hz. Surface electromyography (EMG) was recorded from the left sternocleidomastoidus (STER), anterior deltoid (DELT), latissimus dorsi (LATD), rectus abdominus (RABD), external obliquus (EOBL), biceps femoris (BFEM), rectus femoris (RFEM) and gastrocnemius medialis (GATM). Both the amplified EMG (Noraxon) and voltages from the force table were sampled in Spike 2 at 2500 and 100 samples/s respectively. Pressure beneath the thoracic, lumbar and pelvic regions was recorded between T6 and the greater trochanter at 50 samples/s by a Tekscan pressure mat. The onsets of the 4 phases of movement were determined using the following data: phase 1 – onset of STER EMG activity, phase 2 – movement of the COP towards the feet (Tekscan), phase 3 – beginning of footward pelvis rotation (Vicon), phase 4 – foot contact (Vicon). The duration of each phase was determined as both an absolute time and percentage of total movement time. The EMG data were reduced by identifying the onset and offset of activation of each muscle. Each trial was compared to a single trial at a mid-range speed, and EMG duration was scaled to the same period. The RMS amplitude of EMG for each muscle was compared to that of the mid-range trial.

RESULTS AND DISCUSSION

The overall duration of the sit-up corresponded to an increase in absolute duration of phases 1 and 3 while phases 2 and 4 remained constant (see Figure 1). However, the relative proportion of time in phase 3 decreased with increasing duration, in contrast to the increased duration in phase 1. Thus, the only phase that increased in duration along with overall movement time was phase 1.

Figure 1: Example of the duration of each phase of the sit-up for subject AO.



The intensity of muscle activation depended upon the phase of movement. For example, STER, DELT and BFEM were predominantly used during the initial trunk curling; thus, activation duration was reduced with the faster sit-ups although this did not necessarily correspond to an increase in activation intensity. During a typical sit-up, the abdominal flexors RABD and EOBL can be activated to near maximal capacity. However, the timing of peak activation of these muscles is crucial. If peak activity occurred too early, the hips would flex instead of the required trunk flexion. The timing of activation of these muscles did not scale to the duration of the task, even though the onset of activity occurred in phase 1. These observations suggest that, rather than using a generalized motor program for different speeds of movement, other factors may influence the motor pattern. For example, proprioceptive information may influence the timing of peak activation of the trunk flexors.

SUMMARY

The sit-up is a mechanically complex task, whereby approximately two thirds of the body's mass must be lifted over the pivot point. Increasing the speed of the sit-up results in scaling of only part of the movement, suggesting that the durations of the non-scaled phases are limited by the mechanical requirements of the task. The detailed timing of the motor pattern might be influenced by proprioception.

REFERENCES

Cordo, P.J., et al. (2003) The sit-up: complex kinematics and muscle activity in a voluntary axial movement. *J. Electromyography Kinesiology*, in press.

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