A CASE STUDY OF MUSCLE ACTIVITY IN GIANT SLALOM SKIING

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INTRODUCTION

Previous research has been helpful in providing a basic understanding of the response of the muscular system during skiing. Asang et al. (1975) and his colleagues (Grimm, 1978) were some of the first investigators to use telemetry with electromyography (EMG) during skiing. They monitored surface EMG from four leg muscles in conjunction with force from a dynamometer between the binding and bottom of a boot to study six skiing styles ranging from a herringbone step to a parallel swing. Karlsson et al. (1978) looked at differences in EMG between a recreational skier and a competitive skier while skiing a slalom course. Muscle activity of the competitive skier was more dynamic, with discrete bursts of activity, than the recreational skier who displayed more continuous activity at a lower intensity.

Other researchers have concentrated on the relationship between EMG and loads placed on the knee and leg for the purpose of injury prevention. Louie et al. (1984) examined the relationship between EMG of six leg muscles and torsion of the lower extremity measured with an instrumented ski binding. No significant relationships resulted from the on-snow experiments with three subjects. Maxwell and Hull (1989) compared loads measured from a dynamometer between the ski and boot with EMG activity from six muscles crossing the knee joint. Performance criteria for ski bindings were recommended based on knee loads.

Although the cited literature has provided some fundamental data regarding patterns of muscle activity during skiing, only one of the subjects was a competitive racer. Significant changes in ski equipment over the last fifteen years may also confound comparisons between older studies and the muscular activity and resulting motion used in the current disciplines of alpine ski racing. The present case study used EMG and video data to describe the muscle activity and general motion of an elite skier during giant slalom (GS) skiing.

METHODOLOGY

One female U.S. Ski Team member (age: 20 yrs, stature: 162.6 cm, mass: 56.4 kg) gave her written informed consent to participate in this study.

EMG: Bipolar surface electrodes (Ag-Ag/Cl) were placed over eleven muscle groups on the right side of the body. Muscles of the lower leg (anterior tibialis (AT) and lateral gastrocnemius (LG)), thigh (vastus medialis (VM), vastus lateralis (VL), rectus femoris (RF), medial hamstrings (MH), adductor (AD), and gluteus maximus (GM)), and trunk (rectus abdominis (RA), external obliques (EO), and erector spinae (ES)) were monitored.

Maximal voluntary contractions (MVC) were obtained pre- and post-skiing. Mean MVC's provided a relative reference for the amplitude of muscle activity. Dynamic EMG activity was monitored via telemetry with a four channel transmitter (Noraxon, Inc., Scottsdale, AZ) that was positioned on the subject's lower back with a belt. The EMG signals (bandwidth 10 - 700 Hz) were sampled at 1000 Hz, full wave rectified and integrated every 15 ms with a hardware interface and recorded on computer disk and video. Dynamic EMG was analyzed for peak amplitude (uV) and duration of contraction (ms). Peak EMG was expressed as a percentage of MVC (%MVC).

Video: Video recordings of the skier were made with a 30 Hz camera (Panasonic 5100) that was panned to follow the skier down the course. The video and EMG recordings were genlocked and synchronized using time code recorded on each tape.

Protocol: Since only four channels could be monitored at once, the muscles were partitioned into three sets. Set 1 included the AT, LG, VM, and MH. Set 2 consisted of the VL, RF, AD, and MH. Set 3 was made up of the RA, ES, GM, and EO. The subject skied three runs of a seven gate giant slalom (GS) course for each muscle set: a total of nine runs. Each run was approximately ten seconds in duration, with three to six minutes between each start. Since the first turn was to the left, the right leg was the outside leg for odd numbered gates and the inside leg for even numbered gates. Gates 3, 4 and 5 were selected for analysis. In addition to including two turns to the left (the instrumented right side was dominant) and one to the right, these middle gates were chosen because the subject was up to speed, in the rhythm of the course, and was constrained by gates before and after each turn. Peak amplitude and time measures were averaged across trials for each gate. However, for muscle Set 1 the number of trials contributing to the mean was variable due to missing data. Comparisons were not made between different gates.

RESULTS

Peak activity for six of the eleven muscles occurred when the right leg was dominant in the turn (gates 3 and 5). The exception to this pattern was for the ES muscles of the lower back which reached peak activity when the right leg was on the inside of the turn (gate 4). The AT, RF, AD, and VL, illustrated variable patterns across runs.

Peak amplitudes and coefficients of variation (CV) for the three muscle sets are listed in Table 1. The %MVC for muscle set 1 ranged from 83-110% when the right leg was on the outside of the turn, and from 62-90% of MVC when the right leg was on the inside. The CV's ranged from 2.3 to 36.9%, with six trials greater than 12%, indicating a large amount of variation in amplitude.

For the second muscle set, the mean %MVC ranged from 52% (MH at gate 4) to 206% (AD at gate 5). There was only 5-14% difference in mean %MVC for the RF (156-170%) and VL (125-130%) between left and right turns, indicating a fairly consistent level of muscle activity. Again, CV's were greater than 12% with one exception (RF at gate 4).

Peak amplitudes for set 3 ranged from 27% (EO at gate 4) to 144% MVC (GM at gate 3). CV's ranged from a low of 8.1% (GM at gate 3) to a high of 130% (EO at gate 4).

Mean duration of EMG activity during the ski turns was fairly consistent for the three muscle sets, ranging from 1.08 to 1.56 s. Roughly two-thirds of the CV's were less than 14%, indicating that the timing was more consistent than the peak EMG. The turning phase lasted 63-68% of the total turn, versus 18-21% for initiation and 10-19% for the completion phase.

Table 1. Mean EMG amplitude (%MVC) and coefficients of variation (in parentheses) for 3 sets of muscles during 3 ski turns. The instrumented leg was on the outside of the turn for gates 3 and 5, and inside for gate 4. N = 3 trials except as noted; ξ = 2 trials, ψ = 1 trial.

Gate	Peak EMG (%MVC)							
Set 1	AT		LG		VM		MH	
3	96.0	(14.7)	93.4 ξ	(36.9)	110.6	(7.9)	83.1	(18.0)
4	90.4 ξ	(17.4)	90.4 ψ		80.6 ξ	(2.3)	62.2 ξ	(4.2)
5	95.9 ξ	(27.8)	94.7 ψ		100.8 ξ	(23.3)	101.2 ξ	(6.0)
Set 2	RF		AD		VL		MH	
3	164.4	(36.4)	198.7	(26.7)	127.6	(35.4)	113.2	(28.5)
4	155.8	(8.3)	154.0	(15.5)	125.3	(12.7)	52.0	(19.6)
5	169.5	(33.1)	206.1	(22.9)	130.0	(33.8)	112.5	(30.3)
Set 3	RA		ES		GM		EO	
3	113.1	(21.5)	57.3	(32.8)	144.2	(8.1)	43.6	(97.5)
4	33.9	(22.9)	85.1	(12.5)	73.1	(54.9)	27.1	(130.0)
5	103.7	(21.1)	58.2	(13.8)	139.7	(11.8)	41.3	(103.5)

DISCUSSION

Examination of the EMG recordings revealed an abundance of activity for most muscles. In Set 1, the amplitude of the AT and LG, which function in dorsi- and plantar flexion of the foot, respectively, was 90% of MVC or greater during turns in both directions. The AT and LG are the first major muscles that react to and control forces affecting the fore and aft pressure of the ski which may explain the relatively high and constant activity. Peak amplitudes in the VM and MH, which function in leg extension and flexion, respectively, were approximately 20-30% greater when the right leg was the outside and primary support leg in the turn. In that position, the VM is attempting to resist gravitational and centrifugal forces and maintain the proper amount of leg extension for support. The MH are active as stabilizers of the knee and maintain the quasi static position by balancing the extensor forces of the VM.

In the second muscle set, the %MVC for the AD and MH was approximately 50% greater when the right leg was the outside leg in the turn. In skiing, contraction of the AD is primarily responsible for knee angulation, a likely explanation for the increased activity during initiation of the turn. Because the RF crosses the knee and the hip, it functions as an extensor of the lower leg and as a flexor of the thigh. When the right leg is on the inside of a turn, the thigh is flexed more than when the leg is on the outside, resulting in EMG activity that is most likely due to the RF's function as a hip flexor.

The activity of the VL was consistent with the leg extension function of the quadriceps. A similar level of activity when the leg was on the inside of the turn was unexpected and may be due to contact of the lateral edge of the inside ski on the snow during the turn. One may speculate that supporting forces of the inside leg are being absorbed predominantly by the lateral side and may be responsible for the level of activity in the VL.

There is no obvious explanation for the large variability in peak EMG of the EO. One would expect that the EO would be fairly active in the turn since they are responsible for twisting or rotational movements and stabilization of the trunk relative to the lower body.

The RA and GM followed the more general trend of greater %MVC (approximately 70%) when the right leg was on the outside of the turn. The RA flexes the trunk and/or thighs, bringing the body into the crouched position observed during the turn. The GM is a thigh extensor and provides a similar function of extension and stabilization about the hip that the quadriceps provide about the knee joint.

In contrast to the general trend cited above, the ES exhibited peak EMG activity when the right side of the body was on the inside of the turn. This trend was fairly distinct as evidenced by a CV of 12.5% at gate 4. The ES are responsible for trunk extension and opposing flexion of the trunk. Entering a turn, the trunk is flexed as the skier drops into a low position, and then extended as the skier rises out of the turn. In the transition from flexion to extension, the ES are contracting under eccentric conditions and experience their greatest loading. The banked and countered position of the skier at this phase may be responsible for the greater EMG activity of the ES when on the inside of a turn.

Since the muscle contractions are roughly correlated to the time spent in each turn, the duration of muscle activity is partially dependent on the spacing of the gates. For the GS turns examined in this investigation, average times of 1-1.56 s per turn represents a relatively long duration of muscle activity compared to most sports. For example, the arm cocking and acceleration phases of the arm in pitching lasts approximately 0.145s (Dillman 1993). The duration of muscle activity further emphasizes the quasi static nature of muscle function during GS turns.

CONCLUSIONS

The following conclusions derived from this investigation must be interpreted with caution, since the EMG patterns from only one skier were examined: 1) there is substantial muscle activity at large %MVC (83-206%) with considerable variability; 2) timing was less variable than peak amplitude; 3) the trunk muscles are involved with the ES being more active when on the inside and with the trunk in a countered position; and 4) the amount of co-contraction between opposing muscles and the duration of muscle activity per turn (1-1.56s, 65% in the turning phase) suggests a quasi static nature of muscle activity during a GS turn.

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