Muscle Use During Low-Impact Aerobic Exercise (Gliding) Compared to Conventional Weight Lifting Equipment, Part 2

Jerrold S. Petrofsky, PhD, JD
Jennifer Hill, BS
Ashley Hanson
Amy Morris, BS
Julie Bonacci, BS
Rachel Jorritsma, BS

Azusa Pacific University, Department of Physical Therapy, Azusa, California
Loma Linda University, Department of Physical Therapy, Loma Linda, California

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ABSTRACT

Six subjects between the ages of 18 and 35 years old were examined to compare muscle use. The rectus abdominus, erector spinal, gluteus maximus, quadriceps, hamstring, gastrocnemius, and tibiallis anterior muscles were assessed by electromyogram. Conventional exercise was performed by weight lifting on quadriceps, hamstring, abdominal and back extension machines and then compared to low-impact aerobic exercise involving extension of the legs on inexpensive discs that slide on the floor, a technique called Gliding. Subjects performed a maximum effort for each muscle and by measuring the maximum electromyogram, data could then be normalized to assess muscle use during the various exercises. The results of the experiments showed that although there is no external resistance in low-impact aerobics Gliding, the equivalent muscle activity was that of moderate exercise on conventional strength training exercise machines. For example, the level of muscle activity of the central core stabilizing muscles (rectus abdominus and paraspinals) during Gliding was equivalent to loads of 54 kg and 36 kg, respectively, during trunk flexion and extension on commercial exercise equipment. Thus effective muscle training can be accomplished with the use of inexpensive Gliding exercises.

INTRODUCTION

It is always assumed that heavy anaerobic exercise is necessary to increase the activity of muscles to the point where muscles can be strength trained.[1,2] However, recent papers have shown that considerable muscle activity, as assessed by electromyogram (EMG), can be seen in individuals who are healthy, but not athletes during even intermittent prone back extension exercises.[3] In these experiments, exercise was broken into 4 one-second segments while subjects were lying prone on a

Table 1. General Characteristics of Subjects*

	Age (years)	Height (cm)	Weight (kg)
Mean	25.3	169.9	69.8
SD	1.5	6.7	9.6

*Male (n = 4), female (n = 2)

bench and raising their trunk to a horizontal position. Muscle activity was measured in the erector spinae, gluteus maximus and hamstring muscles. Electromyographic analysis showed significant fatigue in the lumbar and hip extensor muscles, which was unrelated to gender. Even walking in water can result in considerable muscle activity.[4,5] While lower body exercise is often used to exercise the legs, exercise involving standing activity also involves considerable activity in the core muscles.[6] For example, abdominal muscle activity during pelvic tilt exercise was significantly higher than in abdominal flexion types of exercise.[7] In these types of combined exercises, where leg and abdominal exercises are combined, adduction or abduction did not increase quadriceps EMG activity.[8] If, however, the muscles exercised, are closer to the core muscles (such as gluteus maximus), substitution can occur and the abdominal muscles can be used to help control the hip joint.[9]

Thus, any type of exercise in the lower body that involves stabilization of the core muscles will involve considerable muscle activity in the core muscles, which has largely gone unnoticed in previous studies.[10] Most studies have concentrated on running, cycling or skiing, exercises that largely examine lower leg muscles.[11-14]

Therefore, in the present investigation, we examined the activity in leg muscles and core muscles during lunge exercises to understand the interrelationship in both time and magnitude of muscle use in this type of exercise.

Questions that were addressed about this form of exercise were: 1) Is Gliding a good exercise for muscle training? 2) What is the muscle use during glides and is it limited to a few muscles? 3) How much core muscle involvement is there? And, finally, 4) how smooth is Gliding exercise when compared to conventional exercise?

SUBJECTS

The 6 subjects (4 male and 2 female) age ranged from 18 to 35 years old. Subjects were fit and free of any cardiovascular or neuromuscular problems, or orthopedic injuries that would prevent their inclusion in these studies. All methods and procedures were explained to each subject and all subjects signed a statement of Informed Consent approved by the Human Review Committee at Azusa Pacific University. The general characteristics of the subjects are listed in the Table 1.

METHODS

Determination of Muscle Activity

Muscle activity was determined through the use of an electromyogram (EMG) (Figure 1). The electromyogram represents an interference pattern that reflects the activity of the underlying muscle.[15] Since the relationship between tension and EMG is linear, the electromyogram was used to assess the extent of muscle activity.[16,17] Muscle activity was therefore assessed by first measuring the maximum EMG of the muscle during a maximal effort (Figure 2) and then, for any given exercise, the percent of maximum EMG achieved

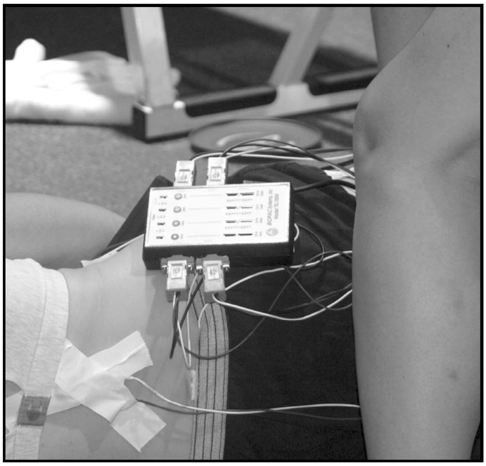

Figure 1. One of the 4 channel EMG telemetry amplifiers used in the study is illustrated. The telemetry amplifier is shown attached to the waist of the subject with EMG electrodes going to the appropriate muscles.

was calculated for muscle activity.[17-19] Two electrodes were applied, one on the belly of the muscle, and one 2 cm distal to the belly of the muscle for any given muscle. A third electrode, the guard, was attached within 4 cm of the 2 active electrodes. The electrical output from the muscle was amplified with a biopotential amplifier whose frequency response was flat from DC to 1000 Hz and amplified with a gain of 5000 (EMG 100c, Biopac Incorporated, Santa Barbara, Calif). The amplified EMG was digitized with an analog to digital converter (12 bit) and sampled at a frequency of 2000 samples per second and stored on an IBM Pentium 4 Digital Computer. The digitizer was an MP100 (Biopac Incorporated, Santa Barbara, Calif). The amplitude of the EMG was analyzed by integrating the digitized data.

PROCEDURES

Two series of experiments were performed on each subject. In the first series of experiments, exercise was performed with a low-impact aerobics exerciser called Gliding; a videotape demonstration was given to the subjects.

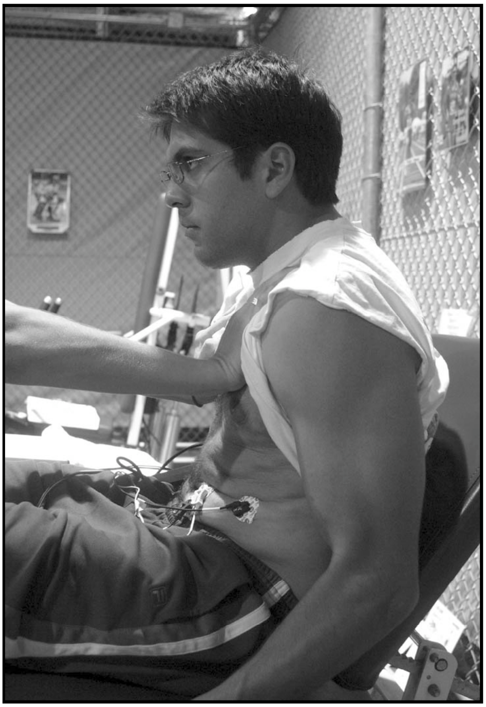

Figure 2. Maximum strength testing of the abdominal muscles is shown. Manual resistance is applied to the abdominal muscles and the subject then exerted a maximum effort. EMG was recorded from the electrodes shown in the diagram to determine a maximum EMG for the given muscle group.

In the second series of experiments, on the same subjects, the same muscles were exercised, but on conventional exercise equipment (ie, quadricep and hamstring weight lifting machines, and abdominal back extension machines). Weight was applied in increasing increments, so that the relationship between weight and EMG activity could be determined on each machine and data cross compared from the machines to the Gliding exercises. For the quadriceps machine, the workloads were 9 kg, 15.9 kg, and 22.7 kg for light, medium, and heavy loads, respectively (Figure 3). For the hamstring machine, loads were set at 9 kg, 13.6 kg, and 18.18 kg respectively. The abdominal flexion machine workloads were set somewhat higher, at 18.1 kg, 36.3 kg, and 54.5 kg for the light, medium, and heavy loads, respectively.

Figure 3. A piece of commercial exercise equipment for exercising the quadriceps muscles is shown. EMG electrodes are attached to the quadriceps, abdominal muscles, and other muscle groups to assess muscle use during exercise at various levels of weight lifting.

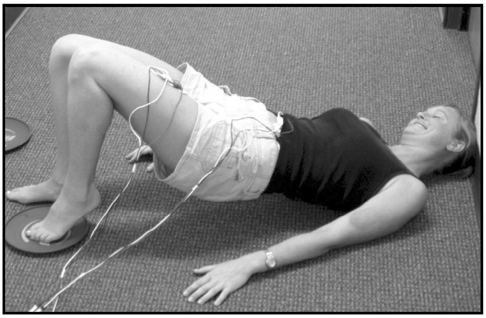

Figure 4. This figure shows a subject performing a Gliding exercise. The exercise shown here is for knee flexion with the hips raised to increase the work.

Finally, for the back extensor muscles, workloads were set at 22.7 kg, 29.5 kg, and 36.3 kg for the light, medium, and heavy loads, respectively.

Table 2 summarizes the exercises examined in this study. These exercises included a side lunge to the right and a side lunge to the left, which involved

Table 2. Exercises Examined in the Study*

Side lunge right		A
Side lunge left		B
Back lunge left		C
Back lunge right		D
Supine ham curl		E
Supine ham bridge	1 leg	F
Supine ham b2	2 legs	G
Side lying hip ab ad		H
Side lying hip ab ad bridge		I
Supine ab ad		J
Supine ab ad hips up on abduction		K
Supine ab ad hips up continuously		L
Sliding squat		M

*Ham indicates hamstrings; and ab ad, adduction and abduction.

adduction and abduction of the hip to either the right or left using the Gliding (Figure 4) to reduce resistance on the ground and make the movement smoother (exercises A, B) (Figures 5, 6). Lunges were also done in the back direction to exercise the gluteals, hamstring, and paraspinal muscles (exercises C, D) (Figure 5). On both lunges, the subject pushed into the floor as the leg was returned to the center position to increase the work on the body.

The next set of exercises was conducted with the subjects lying on their backs (supine) (Figure 5). The Gliding equipment was placed under the feet, and the knees and were alternately extended and flexed (exercises E, F, G). During the first set of exercises, the back was flat on the floor (exercise E). During the second set of exercises, the hips were lifted to a bridging position during flexion of the leg (bridging) through use of the gluteal and lower back muscles (exercise F). The final progression was to bridge the lower back

Figure 5. A subject performing a Gliding exercise, a lunge to strengthen the core muscles and the legs through Gliding.

Figure 6. This figure shows a subject performing a Gliding exercise during abdominal adduction.

during the entire flexion/extension progression on the knee (exercise E).

Another set of exercises was performed with the subject side lying. With the trunk supported on the right arm and the elbow bent at 90 degrees (exercises H, I). The hip was flexed and extended through full range of motion (exercise H). In the second progression of this exercise, the hips were lifted off the floor during the exercise to increase work on the core muscles (exercise I). Another supine exercise was the supine abductor-adductor. The subject lay supine with the Gliding under the feet, and the hips were abducted and adducted (exercises J, K, L). This was accomplished with the hips on the floor (exercise J), with the hips raised on abduction only (exercise K) and the hips raised throughout the entire exercise (exercise L).

Finally, a series of sliding squats were done simulate ice skating movement. This involved sliding the legs out while squatting and then moving back to a neutral position (exercise M).

Statistical Analysis

Statistical analysis involved the calcula-

Table 3. Muscle Use Data from Commercial Weight Lifting Equipment (% of Maximum Muscle Activity)*

Exercise	Abs	Paraspinal	Quads	Hams	Abductor	Adductors	Gluteus	Gastroc
quad low	22.67	24.05	24.85	5.83	8.67	12.19	18.92	3.67
quad med	18.13	25.54	33.83	7.67	6.83	24.57	20.60	4.83
quad high	28.60	31.37	49.50	8.67	12.17	27.93	25.48	5.50
ham low	18.57	30.92	13.00	21.67	15.30	11.46	36.20	11.05
ham med	26.56	33.40	13.64	29.35	15.75	24.82	40.41	5.50
ham high	29.17	36.96	16.83	43.57	16.23	29.99	43.76	6.10
abd low	26.33	6.50	6.00	14.83	8.00	13.12	16.75	6.50
abd med	34.49	11.87	5.83	9.00	10.00	10.50	7.89	5.83
abd high	44.00	4.83	4.50	10.00	6.50	7.00	20.89	4.33
back low	5.00	27.54	7.17	6.50	9.24	8.70	4.67	8.51
back med	8.50	31.25	6.50	6.50	8.27	7.00	5.83	6.83
back high	8.83	40.94	7.67	7.47	6.00	7.86	7.50	10.24

*Abs indicate abdominals; quads, quadriceps; hams, hamstring; and gastroc, gastrocnemius.

tions of means, standard deviations, and *t* tests. ANOVA was also used to compare data between groups. The level of significance was $P < 0.05$.

RESULTS

The data on conventional weight lifting equipment as a function of the total muscle activity as assessed by EMG is shown in Table 3. The standard deviations for the data are shown in Table 4. Data is shown for the abdominal (rectus abdominus), paraspinal (erector spinae), quadriceps, hamstring, hip abductors, hip adductors, gluteus maximus, and medial gastrocnemius muscles. EMG data is shown as a percent of the maximum muscle activity, as described under methods, for the quadriceps leg extension machine, hamstring machine, abdominal flexion, and back extension machines for 3 different workloads (a low workload, a medium workload, and a high workload).

As shown in Table 3, for the quadriceps machine with low resistance (quad low), the average muscle use of the subjects for the quadriceps was 24.85% of total muscle activity. Muscle activity increased to 33.83% with a medium workload on the quadriceps machine and, for the high workload to 49.5%. The interesting phenomena that occurred on the conventional weight lifting equipment was that, although the equipment is said to isolate specific muscle activity, there was also some muscle activity for the abdominals and paraspinal muscles, as shown in the first 2 columns of Table 3. As can be seen here, there is considerable muscle activity in the abdominals and paraspinal muscles to stabilize the body. For example, for heavy muscle contractions of the quadriceps muscle, 28.6% of the rectus abdominus muscles were active to stabilize the core section of the body. For the paraspinals (longissimus thoracis and spinalis muscles), the muscle was 31.37% active. Thus, with both agonist and antagonist pairs of muscles active in the core of the body, a considerable isometric contraction was being accomplished to stabilize the core to extend the quadriceps muscle. As might be expected, hamstring, hip abductor adductors, and the gastrocnemius were silent. However, the gluteus maximus

Table 4. Standard Deviations of Muscle Use Data from Commercial Weight Lifting Equipment*

Exercise	Abs	Paraspinal	Quads	Hams	Abductor	Adductors	Glut
quad low	2.25	16.29	1.95	1.47	3.14	6.40	9.24
quad med	10.19	11.08	4.40	2.16	2.48	6.73	6.50
quad high	15.43	12.65	6.09	2.58	5.56	9.34	6.16
ham low	7.81	16.55	5.10	8.84	11.53	6.37	10.33
ham med	11.40	13.75	4.24	3.79	7.85	6.91	10.98
ham high	6.55	19.48	5.34	24.68	10.96	12.35	9.47
abd low	4.18	1.87	1.41	4.17	3.03	8.94	8.23
abd med	10.33	1.73	1.72	2.10	6.99	4.32	6.57
abd high	6.36	1.47	1.05	4.65	1.87	4.43	13.56
back low	1.79	11.65	3.76	1.87	6.18	2.62	2.50
back med	2.88	16.02	1.05	1.87	6.86	1.41	1.72
back high	2.32	15.02	2.73	1.03	1.79	4.43	2.43

*Abs indicate abdominals; quads, quadriceps; hams, hamstring; and gastroc, gastrocnemius.

was also used during quadriceps activity, averaging about 25% of total muscle activity for the heaviest load.

The use of muscle during the various types of Gliding exercises examined in this study, as a percent of maximum muscle EMG, or strength is shown in Table 5. Table 6 shows the standard deviations of the muscle use for the same exercises. For the side lunge to the right and left, with electrodes connected to the right side of the body, when the lunge was exerted to the right, considerable activity in the abdominal and paraspinals was seen (Table 5). For example, rectus abdominus activity was 77.1% of the maximum EMG. In addition, to help stabilize the core muscles, para spinals were also active at 53.2% of maximum muscle activity. This was true for the side lunges to the left as well. Core muscles in both cases remained quite active. For the side lunge to the right, only minimal muscle activity was necessary to stabilize the knee (quadriceps and hamstring muscles). Hip adductors were fairly active, at approximately 30% of the maximum strength of the muscles to extend the leg, since the reach was fairly extensive as shown in Figure 6. Abductors were fairly silent as was the gastrocnemius muscle. However, the gluteus maximus muscle was approximately 29.3% active to stabilize the pelvis and extend the leg. When the lunge was to the left, since electrodes were on the right leg, the mirror image was seen. For example, whereas hip adductors were active during the lunge to the right, hip abductors on the right hip were active to extend the leg to the left. The activity of the 2 muscle groups (abductors and adductors) was approximately the same. Abdominal, paraspinal, and gluteus maximus muscle activity was also not statistically different ($P > 0.05$) for the 2 types of exercise. Comparing these data to data for weight lifting equipment for the quadriceps muscle, for example, the exercise was equivalent to exercise at the lowest workload on the quadriceps leg extension machine and the lowest workload on the hamstring machine. However, for the para spinals and abdominals, work was equivalent to the highest setting (for abdominals over 40 kg) on conventional weight lifting machines.

Whereas the abductor and adductor muscles were extremely active during

Table 5. Muscle Use Data During Gliding as a Percent of Maximum Muscle Activity*

Exercise Line	Abs	Paraspinal	Quads	Hams	Abductor	Adductors	Glut	Gastroc	
side lunge r	77.11	53.16	22.33	14.67	12.68	29.08	29.35	4.50	A
side lunge l	62.28	50.74	41.35	11.33	27.43	12.33	34.56	29.87	B
back lunge l	46.72	59.71	8.67	38.72	9.11	15.55	45.52	11.95	C
back lunge r	45.57	55.69	8.83	16.49	13.00	15.85	42.29	18.69	D
supine ham	17.82	24.28	31.01	38.48	15.87	13.13	16.17	22.71	E
supine bridge	27.35	63.18	39.97	56.76	22.93	23.28	61.75	28.89	F
supine ham b2	28.33	87.09	56.33	68.50	28.06	36.40	77.88	66.92	G
side lye hip ext	20.33	16.05	39.19	34.26	12.92	21.66	28.61	12.76	H
hip ext bridge	48.83	51.34	59.55	46.17	18.01	35.83	39.06	15.56	I
supine ab ad	22.00	12.25	6.33	15.00	17.67	18.18	35.30	14.06	J
ab ad 1/2	20.79	35.78	24.84	34.13	24.50	29.82	68.41	11.86	K
ab ad full	26.67	56.00	33.27	78.00	72.00	65.46	79.17	11.33	L
Slide squat r	27.42	30.68	34.04	27.62	25.12	38.00	39.80	27.55	M

*Abs indicate abdominals; quads, quadriceps; hams, hamstring; gastroc, gastrocnemius; ext, extension; and ab ad, adduction and abduction.

Table 6. Standard Deviations of Muscle Use Data During Gliding*

Exercise	Abs	Paraspinal	Quads	Hams	Abductor	Adductors	Glut	Gastroc	Line
side lunge r	30.89	36.60	8.62	6.62	8.06	22.95	9.73	2.66	A
side lunge l	21.13	16.30	9.08	5.09	4.99	5.20	8.42	8.79	B
back lunge l	8.12	7.96	2.80	14.57	3.06	7.75	8.87	7.85	C
back lunge r	12.12	7.07	2.86	2.64	2.61	9.12	9.62	4.32	D
supine ham	9.73	13.07	4.92	17.48	4.00	5.37	3.97	3.75	E
supine bridge	5.42	17.95	5.05	8.90	8.24	6.49	11.25	5.35	F
supine ham b2	2.73	10.06	4.97	3.74	11.00	5.48	5.81	15.73	G
side lye hip ext	5.32	5.53	4.19	3.68	6.45	7.53	6.85	3.44	H
hip ext bridge	5.95	11.85	13.14	8.45	6.44	4.49	12.58	4.79	I
supine ab ad	3.52	5.08	2.16	4.29	4.13	6.31	6.75	5.19	J
ab ad 1/2	4.71	11.75	4.24	4.29	4.37	8.35	11.69	5.76	K
ab ad full	3.20	5.69	5.34	5.02	4.05	11.21	5.19	2.50	L
Sliding squat r	4.85	6.17	8.95	5.04	9.10	7.40	2.95	10.72	M

*Abs indicate abdominals; quads, quadriceps; hams, hamstring; gastroc, gastrocnemius; ext, extension; and ab ad, adduction and abduction.

side lunges, as might be expected, back lunges showed much greater involvement for the gluteus maximus and hamstring muscles. As shown in Table 5, there is a significant increase in activity of the gluteus maximus and hamstring muscles compared to side lunges ($P <$ 0.01). In fact, back lunges used 45.52% of the maximum muscle activity of the gluteus maximus and 38.72% of the maximum activity of the hamstring muscles. Gastrocnemius activity was light, as might be expected, and was only used to stabilize the body. Abdominals and paraspinal activity was similar in magnitude to side lunges in stabilizing the central core area of the body, which is associated with this type of movement.

The next exercises involved a sequence of 3 different exercises with the subject lying supine and the knee being flexed and extended. In the first set of experiments, the subject was lying comfortably in a supine position with the back on the floor and the right leg was flexed and extended using Gliding. Since the Gliding provided low resistance impact and reduced the coefficient of friction between the foot and floor, muscle activity was light. For example, the average hamstring and quadriceps activity, as shown in Table 5, averaged approximately 1/3 of the peak strength of the muscle. Paraspinal and abdominal activity was minimal, averaging approximately 20% of the muscles' maximum strength during the exercise. Abductor/adductor activity was less than 15% of the muscle strength and gluteus maximus was slightly active at 16% of the muscle strength with gastrocnemius intermittently active for peak activity of 22% of the muscle strength.

In contrast, when the hip was extended and lifted during the exercise, results were different. As shown in Table 5, there is a sharp increase in the activity of the paraspinal muscles (erector spinae), increasing from 24.28% to 87.09%, this difference being significant ($P < 0.01$). Quadriceps muscle activity increased as well, but the increase was not significant. The increase in abdominal muscle activity was also insignificant ($P > 0.05$). In contrast, hamstring activity increased to about 2/3 of the muscle's maximum strength. Hip abductors and adductor functioned minimally, whereas gluteus maximus increased to 2/3 of maximum strength. This increase in gluteal activity from the 16% seen with the back resting comfortably on the floor was also significant ($P < 0.01$).

During side lying hip flexion/extension, as was seen in data cited above; muscle activity was dramatically increased when the hip was bridged off the floor during the exercise. As shown in Table 5, when the body was comfortably lying on the floor abdominal and paraspinal activity was low, averaging 20.33% and 16.05% of maximum muscle activity for the abdominal and paraspinal muscles respectively. However, when bridging occurred, abdominal and paraspinal activity increase to 48.8% and 51.34%, these differences being significantly higher ($P < 0.01$). But other muscle activity increased as well. To enable the leg to flex and extend at the hip during bridging, quadriceps and hamstring muscle activity increased significantly ($P < 0.01$). For example, for the quadriceps muscle, muscle activity increased from 39.19% for the subjects' side lying on the floor to 59.55% when the body was lifted to bridge the hip off the floor. The same was true for other muscles as well such as the hip abductors and adductors, which increased slightly in activity, as did the gastrocnemius muscle. Thus, although abductor/adductor activity was not the prime mover associated with this exercise, the muscles were used to the extent that they were necessary to stabilize the body in moving the leg.

The results of the supine abduction/adduction exercises were similar in nature to other exercises involving bridging. When subjects lay on their back and abducted and adducted their hips with the Gliding under their feet, as shown in line J of Table 5, the abdominal and paraspinal activity was low, averaging less than 20% of total muscle activity. Quadriceps activity was low and although abductors/adductors were used in the exercise, activity still averaged less than 20% of total muscle activity. Gluteus maximus activity was somewhat higher but still at only 1/3 of maximum

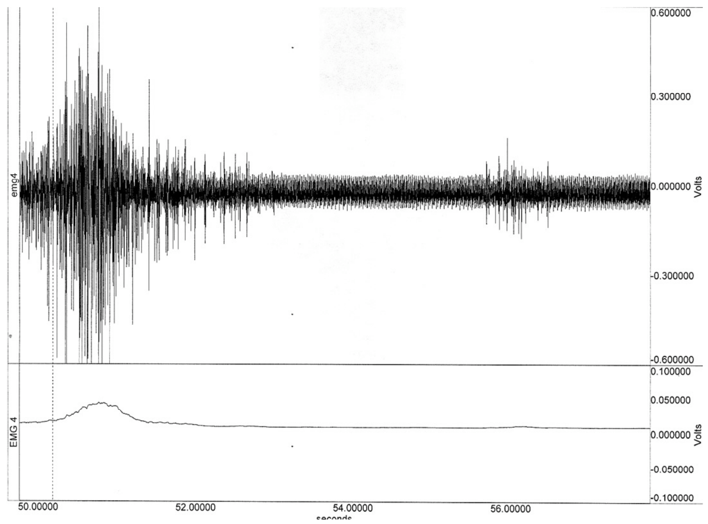

Figure 7. This figure shows the continuous use of muscles during a Gliding exercise (top panel) compared to muscle activity on a quadriceps machine (lower panel).

muscle power. Gastrocnemius activity was also low. However, as shown in line K of Table 5, when the hips were extended to bridge the buttocks off the floor, muscle activity increased in the gluteus maximus muscles to 68% of total muscle activity (this increase being significant, $P < 0.01$) and muscle activity also increased in both the abductors and adductors. Hamstrings nearly doubled activity, as did the quadriceps muscles to maintain body stability during the exercise. When the body was bridged by extending the hips throughout the entire exercise, abdominal and paraspinal activity increased once again (Table 5, line L). The largest increase here was to the paraspinals, where muscle activity increased an average of 56% compared to 35.8% with bridging only half of the time and with no bridging 12%. This increase was significant ($P < 0.01$). The muscle activity of the quadriceps also increased to 33% of maximum, and hamstrings to 78% of maximum muscle activity compared to 34% with a half bridge and 15% with no bridge. Hip abductors/adductors also increased activity. Gastrocnemius showed little change.

Finally, using Gliding with side lunges that mimic ice skating, central core muscle activity in the abdominal and para spinals averaged less than 30% of total muscle activity (Table 5, line M). Quadriceps activity averaged about 1/3 of maximum muscle activity and abduction/adduction approximately 30% of total muscle activity. The gastrocnemius was active at about 40% of total muscle activity.

One noticeable difference in exercise with Gliding versus conventional weight lifting equipment is in the smoothness of the exercise. As shown in Figure 7, the EMG from the hip adductor muscles during a lateral lunge showed remarkable smoothness in the raw EMG (upper trace) or the integrated EMG (lower trace). The time base was over a 2 second period showing a gradual buildup of force and reduction in force during lateral extension of the leg. The weight lifting equipment had a much more abrupt change in muscle activity than seen for the Gliding exercise. For example, the muscle activity of the hamstring muscle in the lower panel of Figure 7 shows abrupt bursts of EMG during exercise on a hamstring machine. This same was true for all muscles and all exercises.

DISCUSSION

Since the classic work of Bigland and Lippold,[15] it has been shown that there is a linear relationship between EMG and tension in muscle. Other investigators have found the same relationship.[20,21] EMG has been commonly used for assessing the tension developed in muscle or the degree of fatigue in muscle during either isometric or dynamic exercise.[18,20,22-25] Under the assumption that the amplitude of the surface EMG is directly related to force, investigators have used the surface EMG to quantify activity of muscles.[26] However, since the amplitude of the EMG increases with both muscle fatigue and tension exerted by the muscle, it is also necessary, during fatiguing exercise, to examine the frequency components of the EMG to properly assess the activity in the muscle.[18,19,23] While some of the variation in EMG can be attributed to the type of electrode (surface versus needle) or the size or position of the electrodes, many differences in EMG from day-to-day still remain to be explained.[27-30] Therefore, in the present investigation, the EMG was normalized in each experiment against the subjects' maximum effort. By doing this, there is little variation from day-to-day.

In the present investigation, muscle activity was determined through surface EMG. The workouts were kept short to avoid the frequency and amplitude changes in EMG that are associated with muscle fatigue. As demonstrated in the present investigation, EMG activity, when normalized for the percent of total muscle activity, can adequately reflect the use of muscle for core muscles and lower body muscles.

There are two significant findings in these experiments. First, the addition of the Gliding equipment under the feet made the exercise very smooth. As evidenced from EMG data, compared to commercial gym equipment, the muscles worked very smoothly and tension was never rapidly developed. There are two common ways that exercise can cause fractures: (1) when too much tension is exerted, and (2) when tension is exerted too fast. By using Gliding, the tension was increased and decreased slowly, so that the chance of injury to the joints and muscle is small.

Another advantage of Gliding is that the core muscles must work hard to maintain the stability of the body during the exercise. As demonstrated here, the level of exercise during Gliding was equivalent to a workout on commercial exercise equipment that would cause enough fatigue to build strength. Significant core strengthening is highly correlated with less lower back pain and fewer back injuries. Therefore, strengthening of these muscles is a key to increasing a healthy lifestyle.

A final advantage of these exercises is that many more muscle groups were involved in the exercise than would be used on typical strength training gym equipment. To exercise all of the muscle groups seen here would require many pieces of commercial exercise equipment and considerable time to accomplish exercise on all of these devices. Here, exercise was fast and efficient. Depending on the exercise, work was equivalent to over 20 kg of load on commercial equipment. It was striking that the level of abdominal exercise during the more advanced Gliding exercises exceeded 40 kg of exercise on an abdominal exerciser. Thus a Gliding technique is not just a way of accomplishing aerobic exercise, but the workout can be heavy, such as in the supine exercise with the hips bridged. By pushing harder into the floor during Gliding, the workload can be increased to a higher level. Thus work can be increased to levels that cause significant muscle training. Further, since muscles work through a large range of motion, the exercise is more effective in a workout. However, EMG data showed that the exercise was directed in the plane of motion of the exercise itself and there was little accessory muscle activity that might lead to injuries.

Any exercise technique that can be accomplished at home with the equivalence of gym equipment and better safety is a goal of exercise physiology. This equipment tested here meets that goal. In summary, Gliding allows smooth muscle contraction throughout exercise at a substantial range of motion; uses primary muscles for a given movement without accessory muscle use that could cause injury; uses substantial core muscle activity which promotes core strengthening; and, uses body weight to increase the work during exercise.

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