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Comparison of Lower Extremity EMG Between the 2-Leg Squat and Modified Single-Leg Squat in Female Athletes

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Purpose: To compare EMG activity of selected hip and knee muscle groups in female athletes performing a modified single-leg squat and the 2-leg squat using the same relative intensity. ***Methods:*** Eleven Division I female athletes from a variety of sports (soccer, softball, and track) completed the study. EMG measurements were taken as the subjects completed 3 parallel repetitions at 85% of their 3-repetition maximum on each exercise. Mean and mean peak EMG data from the gluteus medius, hamstrings, and quadriceps and the quadriceps:hamstrings EMG ratio were compared between the 2 exercises. ***Results:*** Statistically higher mean ($P < .01$) and mean peak ($P < .05$) gluteus medius and mean and mean peak ($P < .01$) hamstring EMG activity occurred during the modified single-leg squat. The 2-leg squat produced higher mean and mean peak ($P < .05$) quadriceps activity and a higher quadriceps:hamstrings EMG ratio ($P < .01$). ***Conclusion:*** Muscle-recruitment patterns appear to differ between the 2 types of squat exercises when performed at the same relative intensity by female athletes.

Keywords: unilateral, resistance exercise, gluteus medius, hamstrings

Single-leg, closed-chain exercises have recently been suggested for knee rehabilitation because of the low shear forces placed on the joint compared with open-chain exercises and the specificity to weight-bearing activities.[1,2] Although most skills in athletic competitions are performed unilaterally or with most of the resistance transferred to 1 leg while in a 2-leg stance, anecdotal evidence has indicated that the 2-leg squat (TLS) is the exercise most commonly used by athletes to increase lower body strength. Thus, to achieve specificity through training for single-leg, weight-bearing activities, the single-leg squat (SLS) has been implemented into strength-training programs and clinical settings. However, because of the lack of research studies analyzing muscle-activation patterns at the hip and knee, the specific benefits of implementing the TLS and SLS into strength-training and rehabilitation programs are not clearly understood.

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In comparison with the TLS, the SLS has a reduced mediolateral base of support that may demand higher neuromuscular activity to support the body in the frontal plane. The reduced base of support likely yields positive neuromuscular demands that more closely mimic strength and proprioceptive requirements in functional and athletic activities. It has been suggested that strengthening the quadriceps and hamstrings while maintaining an appropriate strength ratio between these muscles might provide knee stabilization and prevent knee injury.[3] In addition, hip-abductor weakness might reduce the ability to resist knee motion in the frontal plane.[4] The SLS appears to be an appropriate exercise to strengthen these muscle groups; however, performing it with a load added to the weight of the body is difficult because of the unstable nature of the exercise. With highly unstable exercises, the inability to maintain proper technique with added resistance reduces the ability of the primary muscle groups to produce tension during the exercise,[5] thus limiting the potential for conditioning the lower body for high-intensity activities that occur in sport and daily living.

Behm et al[5] found that the ability to produce force is significantly reduced with unstable resistance exercises and suggested that exercises with moderate instability may optimize motor recruitment while producing the high forces required for strength improvement. Moderately unstable exercises appear to be best suited for athletes to gain strength by challenging the neuromuscular system to control the resistance at higher loads. A modified SLS (MSLS) is performed by supporting the toes of the nonstance foot on a stable structure placed behind the body, which provides increased support to the SLS. With added anteroposterior support from the trail leg, the MSLS can be used as a progression from the more stable TLS to the least stable SLS. During rehabilitation, body-weight resistance and light loads can be used to modify the intensity, and larger loads can be used during a strength-training program.[6] Although there is a wide anteroposterior base of support during the MSLS, instability comes from contacting the support surface with only the top of the trail foot. Using the trail leg for support produces a wider mediolateral base of support than the SLS but smaller than the TLS. These differences in stability likely produce differences in the muscle-activation patterns at the hip and knee. Research has revealed that low hamstring activity relative to the amount of quadriceps activity occurs during the TLS.[7,8] In addition, although research has shown that the hip abductors are active during the SLS and in gait,[9] no known studies have compared hip-abductor, quadriceps, and hamstring activity between the TLS and MSLS. High hip-abductor and hamstring activation may occur during the MSLS because of the moderate size of the mediolateral base of support and the ability to add resistance to this more stable variation of the SLS.

There is a dearth of current research investigating muscle-activation patterns during variations of weight-bearing, single-leg exercises. The available research is limited to the use of body-weight resistance, body weight plus an added small percentage of body weight, or body weight with a fixed additional load for all subjects.[10–12] In these studies, the relative resistance is not equal for all subjects, limiting the ability to make comparisons of muscle recruitment across subjects and between exercises. A relative intensity of the subjects' maximum strength (approximately 70–90% to analyze loads used during strength training) should be the same for each exercise and included to make meaningful muscle-recruitment comparisons. A comparison of muscle recruitment between the TLS and the MSLS using the same relative intensity has not been done. Therefore, the purpose of this study was to compare EMG activity of selected hip and knee muscle groups in female athletes while they performed the MSLS and the TLS at the same relative intensity.

Methods

Subjects

Eleven Division I female athletes from a variety of sports (3 soccer, 3 softball, and 5 track and field) completed the study. The subjects' mean age, height, and mass were 20.63 ± 1.03 years, 1.67 ± 0.11 m, and 59.37 ± 4.00 kg, respectively. After IRB approval and signing informed-consent forms, each participant was screened for the following exclusionary criteria: any current or previous anterior cruciate ligament injury, reports of self-limiting anterior knee pain, a current ankle or hip injury, current low back pain or disorder, and any current lower extremity muscle strain or ligament sprain. All subjects had previous resistance-training experience (mean of 4.1 y) and were proficient in the TLS. They reported that they had less experience training with lunges and the SLS than training with the TLS and had not trained with the MSLS.

Instrumentation

Seven bipolar silver/silver chloride 1-cm AAMBU-Blue Sensors surface electrodes were used in conjunction with the Biopac MP 100 System and accompanying AcqKnowledge software (Biopac USA Inc) to acquire SEMG data. A nontelemetered system was used that contained shielded leads fastened to the surface electrodes.

Frontal- and sagittal-plane motions were recorded by two 60-Hz video cameras. APAS-XP software (Ariel Dynamics Inc, Downers Grove, IL) synced the 2 video files. For kinematic 2-dimensional analysis a calibration frame with 4 linear points in each plane served to provide the system with stationary reference points. Each file was then trimmed and digitized. After digitization, each plane was transformed by the direct linear-transformation process and filtered using a cubic-spline algorithm.[13]

Procedures

Subjects reported for 1 practice session on the TLS and MSLS. Two sessions separated by 48 hours were used to determine the 3-repetition maximum (3RM; maximum load lifted for 3 repetitions) on the TLS followed by 2 sessions to determine the MSLS 3RM. The estimated 3RM determined during the first session was used to more accurately determine the 3RM during the second strength assessment for each exercise. Strength scores determined from the second strength assessment were used to calculate the load that would be lifted during the EMG tests. A minimum of 48 hours after completing the strength assessments, the subjects reported for 1 session to complete the EMG data collection on the TLS and MSLS.

In the practice session the subjects practiced both exercises and received proper technique instruction and written and verbal instructions explaining the EMG procedures. The subjects placed the top of the toes of the trail leg on a 12-in platform to complete the MSLS (Figures 1 and 2). During practice of the TLS, the degree of anterior knee translation relative to the toes was subjectively assessed to correct excessive translation past the toes. During practice of the MSLS, the distance between the front edge of the box supporting the trail leg and the lead toes (39–45 in) that simulated the TLS knee position over the toes was determined for each subject. This measurement was used during the 3RM and EMG tests. The subjects performed each lift using an audio feedback monitor (Bigger Faster Stronger, Salt Lake City, UT) across the middle of the thigh that was activated when the thigh reached a parallel position. Before these tests, a manual goniometer was used to determine that the audio monitor activated when the femur was at the parallel position. For both exercises, the subjects practiced the technique by completing 2 or 3 sets of 5 repetitions with light loads. The dominant leg, determined to be the leg used to kick a ball, was used as the lead leg to perform the MSLS and was the leg used for electrode placement for the MSLS and TLS during EMG data collection. The subjects were instructed to perform the lifts at their own consistent

Figure 1 — Starting position for the modified single-leg squat.

pace while controlling the resistance. Pace was practiced using verbal pacing cues with instructional feedback during these practice sessions and during the warm-up before EMG testing. Subjects were instructed to maintain good upper body posture by maintaining a natural curve in the low back with the chest up while flexing and extending the hip and knee during descent and ascent. Excessive trunk flexion was corrected during these sessions. These criteria were used to determine a successful trial during strength assessments and EMG data collection.

During the 3RM tests, procedures were followed from previously established research on the MSLS,[6] which provided the ability to determine a submaximal intensity, making muscle-recruitment data comparison meaningful between these exercises. A barbell with free-weight plates was used as resistance for the TLS and MSLS. The subjects completed a 5-minute warm-up jog and dynamic stretches followed by 2 warm-up sets using light weight. The 3RM trials took place on the third and successive sets. For each successful trial 10% to 20% of the load was added to the weight with 3 to 5 minutes of rest between trials until the 3RM was

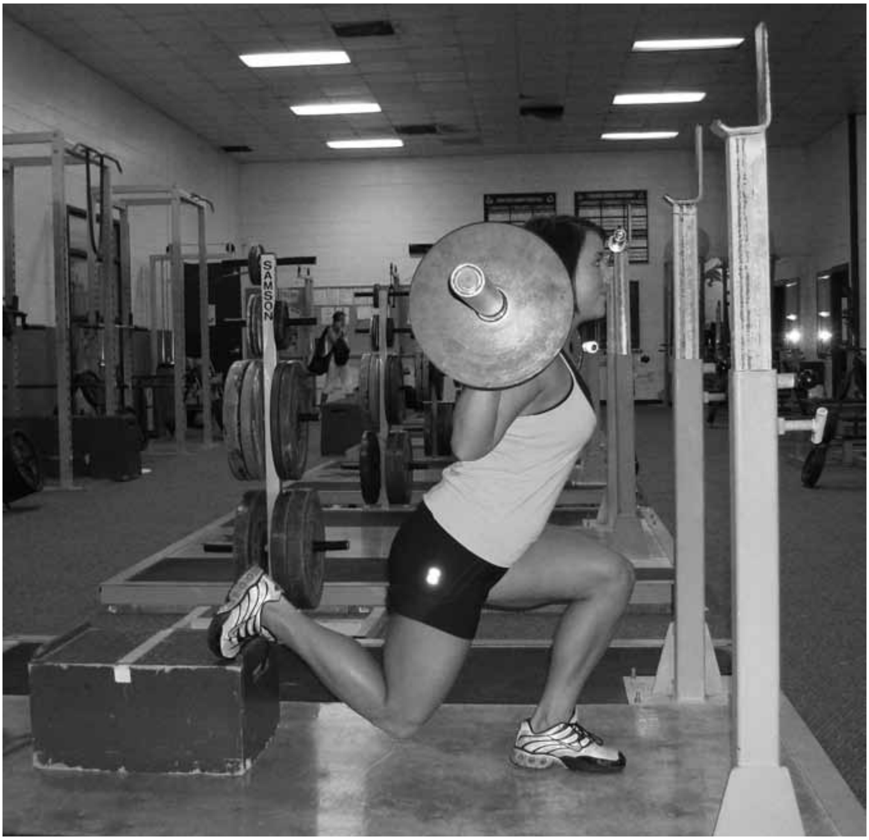


Figure 2 — Modified single-leg squat.

determined for the TLS and MSLS.[14] Maximum lifts were determined within 4 test trials during each of the noted strength sessions.

For EMG testing, before electrode placement each subject's skin was lightly abraded and then cleansed with an alcohol wipe. Electrodes were placed 2 cm apart and parallel to the fiber direction of the gluteus medius, rectus femoris, and biceps femoris on the dominant leg for the TLS and MSLS.[15] The final ground electrode was placed on the tibial tuberosity. Before EMG analysis, the subject abducted the thigh while standing to detect the presence of gluteus medius activity, flexed the knee to detect hamstring activity, and extended the knee to detect quadriceps activity and ensure that excessive noise (3 mV) did not occur. A marker was inserted into the raw sEMG signal to designate the beginning, point of full flexion, and end of each squat.

Eighty-five percent of the subject's 3RM on the TLS and MSLS was used for the TLS and MSLS EMG test. The subjects completed 3 repetitions on the TLS and MSLS during 1 session in randomized order with a 5-minute rest between exercise tests to determine the EMG recruitment levels. After a proper warm-up and dynamic stretches, 2 warm-up sets were completed using light loads. The MSLS EMG tests were performed while standing on a force plate (Zelocity, Scottsdale, AZ) to determine the percentage of the resistance supported on each leg. The audio feedback monitor was used to help subjects attain the parallel squat position. To reproduce natural technique that would be executed during training, the subjects performed the repetitions at their own pace.

During video analysis, the cameras were positioned 90° to the sagittal and frontal planes while aligned with the bar and dominant leg. Video and EMG data could not be synchronized for analysis. The digitized points for the sagittal plane included passive reflective ball markers that were placed on the dorsal aspect of the fifth metatarsal, lateral malleolus, fibular head, femoral condyle, greater trochanter of the femur, iliac crest, and the lateral aspect of the barbell. The frontal-plane points included the midpoint between malleoli, below the tibial tuberosity, and the anterosuperior iliac spine prominence. For each view, manual digitizing was performed for 6 frames with automatic digitization for the following frames. Maximum angles of trunk inclination and dynamic knee valgum were identified for each trial under each condition and then averaged for analysis. Trunk inclination was measured as the angle of the segment from the iliac crest to the end of the bar as it deviated from the sagittal plane, and knee valgum was defined as the deviated angle in the frontal plane using the segment from the midmalleoli to the patella.

Data Reduction

For EMG collection the gain was set at 500 with a common-mode rejection ratio of 110 dB. Raw-data acquisition occurred with a bandwidth setting of 10 to 500 Hz. The location of muscle activation was determined first using the Hodges and Bui[16] detection algorithm. The raw signal was then smoothed using the root mean square with a 50-millisecond window. A linear-envelope technique for each muscle yielded the mean electrical activity. The mean peak electrical activity was derived by a linear envelope of 0.25 seconds surrounding the peak mV activity (0.125 seconds above and below) for each repetition and was calculated from the mean peak scores of the 3 repetitions for each muscle. Mean EMG was calculated by averaging the 3 mean EMG scores during each repetition.

Statistical Analysis

The dependent variables analyzed were the mean and mean peak EMG levels of the gluteus medius, quadriceps (isolation of rectus femoris), and hamstrings (isolation of biceps femoris) and the mean quadriceps-to-hamstrings ratio. Initial descriptive analysis of the data for the 11 participants indicated violations of the assumption of normally distributed data for each of the variables. A visual inspection of stem-and-leaf graphs indicated a bimodal distribution that was consistent across each of the variables. The population distribution of the paired differences was symmetric, so the data were analyzed using nonparametric Wilcoxon signed rank tests for matched pairs. Each Wilcoxon test paired data for the MSLS with the TLS for each of the muscle areas measured. Tests provided z-score and probability values for interpretation. Paired t tests were used to compare differences in maximum dynamic trunk inclination and knee-valgum angle with significance set at $P = .05$. EMG scores were not normalized due to the within-subject analysis because each muscle group's EMG data were compared between the MSLS and TLS, which was performed at the same relative intensity in the same session.

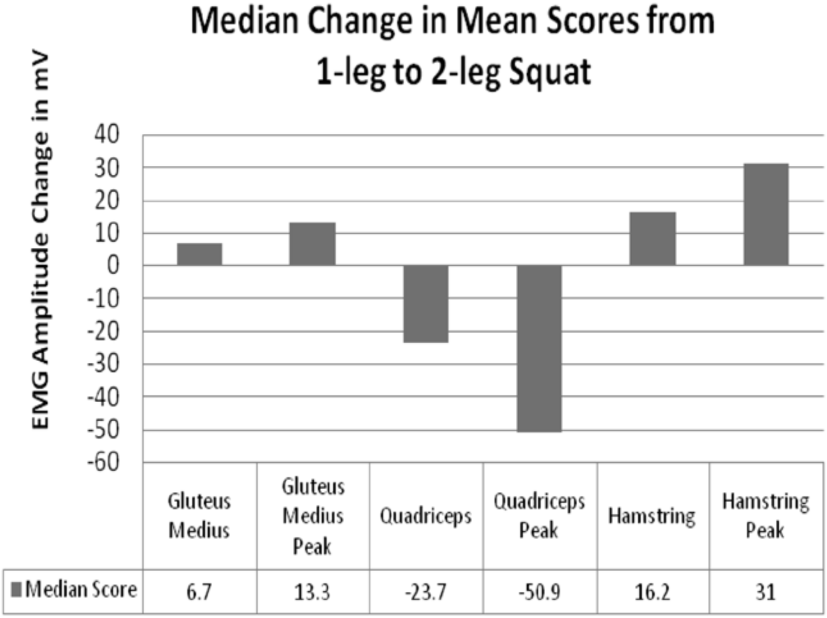
Results

Reported EMG activity indicated different hip and knee muscle-activation patterns for the TLS and the MSLS (Table 1). Statistically significant increases in muscle activation from the TLS to the MSLS were found for mean gluteus medius ($P < .01$), mean peak gluteus medius ($P < .05$), mean hamstring ($P < .01$), and mean peak hamstring ($P < .01$). For the TLS there was a statistically significant increase in activation (over the MSLS) for mean quadriceps ($P < .05$), mean peak quadriceps, and the mean quadriceps:hamstring (Q:H) EMG ($P < .01$). The median differences in the mean scores (average of 3 repetitions) from the MSLS to the TLS are shown in Figure 3, which shows that the MSLS produced higher demands on the gluteus medius and hamstring while the TLS required increased activity from the quadriceps. The mean Q:H EMG ratio for the TLS (4.87) was significantly higher than for the MSLS (1.67; $P < .01$). Maximum trunk inclination was significantly higher during the TLS (40.65° ± 7.0° vs 33.68° ± 7.6°; $P < .05$), and maximum knee-valgum angle was significantly higher during the MSLS (29.4° ± 7.4° vs 21.9° ± 6.9°; $P < .01$).

Table 1 EMG (mV) Amplitude Analysis, Mean (SD)

Measure	Modified single-leg squat	2-leg squat	z	P
Mean gluteus medius	40.25 (48.05)	27.35 (34.58)	2.93	.003**
Mean peak gluteus medius	72.17 (81.37)	57.85 (79.94)	2.13	.033*
Mean hamstrings	57.10 (49.36)	22.95 (21.11)	2.85	.004**
Mean peak hamstrings	103.33(84.44)	60.02 (48.93)	2.85	.004**
Mean quadriceps	70.6 (55.29)	105.44 (91.03)	2.49	.013*
Mean peak quadriceps	171.23 (144.55)	220.22 (179.62)	2.05	.041*

$^{*}P \leq .05$. $^{**}P \leq .01$.



	Gluteus Medius	Gluteus Medius Peak	Quadriceps	Quadriceps Peak	Hamstring	Hamstring Peak
■ Median Score	6.7	13.3	-23.7	-50.9	16.2	31

Figure 3 — Differences in EMG amplitude. Significant differences were found for all comparisons ($P \leq .05$).

Discussion

The findings of our study revealed that higher hamstring and lower quadriceps activity occurred during the MSLS than when performing the TLS at the same relative intensity. During a squat motion, higher hamstring and lower quadriceps activity are suggested to occur with greater hip flexion because of an increase in the moment of force at the hip and a decrease at the knee.[17] In our study mean maximum trunk inclination on the TLS (40.65°), calculated from the 3 repetitions, was greater than the trunk inclination on the MSLS (33.68°). The results from our study indicated that the greater hip flexion during the TLS had minimal effect on hamstring activity. The results are in agreement with those of Caterisano et al,[7] who found no significant change in hamstring activity as the depth of a squat increased along with increased hip flexion. The reduced base of support during the MSLS appeared to have a greater effect on hamstring activity than an increase in trunk inclination during the TLS. The gluteus maximus and trunk musculature may be most active to support the load as trunk inclination increased during the TLS. Greater hip and trunk flexion during a TLS are typically related to less anterior translation of the knee to position the mass over the base of support. To control for possible differences in the movement patterns and moments of force at each joint between the 2 types of squat, the subjects practiced performing the MSLS with the lead knee positioned above the toes similar to the degree of anterior translation of the knee performed during the TLS.

Although several investigations have determined that muscle activity is high in selected lower body muscle groups during the SLS and step-ups,[10–12] low hamstring activity has been found relative to quadriceps activity.[1,2,10–12,18] In contrast to our study, the subjects in those studies performed a body-weight SLS, and Ayotte et al[10] also allowed the subjects to support the body with a hand on a wall during several unilateral weight-bearing exercises. Subjects in the study by Ayotte et al[10] produced 9% to 15% MVIC hamstring activity and 55% to 66% MVIC in the quadriceps, resulting in EMG amplitude Q:H ratios between 4 and 6. However, Youdas et al[19] reported higher hamstring activity relative to quadriceps activity in men (2.52 H:Q ratio) and women (0.71 H:Q ratio) during unstable SLS using body-weight resistance than when performing the SLS squat on a stable surface, 2.25 and 0.62 H:Q ratio, respectively. This previous study suggested that highly unstable squats stimulate an increase in hamstring activity. Our findings also indicated that the moderately unstable MSLS produced a relatively low ratio (1.67) of Q:H recruitment, possibly resulting from the reduced mediolateral base of support and the relatively high resistance. Besier et al[20] found that hamstring-activation patterns occurred during sidestepping and crossover maneuvers to counter varus/valgus and internal/external moments at the knee. In our study higher maximum knee-valgus angles occurred during the MSLS. In addition, we observed several abrupt reversals in movement toward knee varus and valgus directions during each repetition of the MSLS. Thus, biceps femoris activation could have occurred to provide eccentric support during the return from the valgus position. Besier et al[20] concluded that the biceps femoris is active to resist knee internal-rotation moments and produce knee external rotation. Although not measured in our study, knee internal rotation is common during knee-valgus motion[20] and likely occurred during the MSLS. We speculated that biceps femoris recruitment was needed to resist knee internal rotation and produce knee external rotation. Further studies are needed to determine specific activation patterns of all 3 hamstrings with analysis of knee varus/valgus and internal/external rotation motions during the MSLS and TLS.

Several studies have reported high quadriceps and low hamstring activation during the TLS.[7,8,21] Yamashita[22] suggested that low hamstring activation is caused by the inhibition of the muscle during its role as an antagonist with simultaneous hip and knee extension. The mean Q:H EMG ratio found in our study during the TLS (4.87) is similar to results in those previous studies.[7,8,21] The higher quadriceps activity during the TLS is likely a result of the ability to support a portion of the load on the trail leg to assist knee flexion and extension during the MSLS. Higher quadriceps activity during the TLS could have also resulted, in part, from the potential to produce higher knee-extension force with the more stable exercise,[5] indicated by less knee-valgus motion. Quadriceps moment arms provide the potential for recruitment during varus/valgus motions[20]; however, the subjects' lower quadriceps activity and higher valgus motion during the MSLS possibly indicated that selective recruitment of muscles with larger moment arms (eg, biceps femoris) occurred.

Recent studies have also been conducted to investigate the effect of stability on muscle recruitment during the TLS. Anderson and Behm[23] and McBride et al[24] found significantly lower quadriceps activity and force output with higher but not significantly different hamstring activity while the TLS was completed on inflatable discs compared with a stable condition. The subjects in the McBride et al[24] study used machine-supported resistance to complete an isometric TLS. The Q:H

EMG ratio decreased from approximately 5.4 to 2.2 from the stable to unstable condition, which indicates agreement with the findings in our study. Anderson and Behm[23] used lighter loads (body weight, 29 kg, and 60% body mass) for the TLS resistance while the subjects performed the squats using the Smith machine with feet on the floor, free weight with feet on the floor, and free weight with feet on inflated discs. Thus, further research is needed analyzing muscle-recruitment patterns during squats with different bases of support.

Using the same relative intensity is essential for comparing muscle activation among various unilateral and bilateral exercises. Quadriceps and hamstring activity have been compared between the lunge and the TLS.[25] The lunge produced higher quadriceps (40% to 50% MVIC) and hamstring EMG levels (approximately 20% MVIC) on the lead leg than the EMG levels found on the power and front TLS. A 50-lb (~23-kg) bar was used with each exercise, so the relative intensity was higher during the lunge. A high relative intensity was used in our study similar to loads employed to produce strength gains. With the reduced base of support in the MSLS, using high loads may affect hamstring recruitment more than similar relative loads used during the TLS. This speculation is supported by previous studies that reported higher hamstring recruitment during single-leg resistance exercises as the load increased[18,26]; however, these studies did not report relative intensities. In contrast to these previous investigations that analyzed EMG levels of various single-leg exercises and the lunge, the subjects in our study used the same relative intensity during the MSLS and the TLS.

Hefzy et al[27] showed that 75% of the resistance is placed on the front leg during a lunge exercise, which supported the notion that higher relative intensities occur during the lunge than the TLS when the same load is lifted. In comparison with the Hefzy et al[27] study, the subjects in our study supported a mean of 85.16% of the total weight (body weight and added resistance) on the lead leg through the range of motion during the 3 repetitions on the MSLS with only the use of the top of the toes to support the trail leg.

The MSLS produced higher EMG activity in the gluteus medius than the TLS at the same relative intensity. The gluteus medius was likely active to support the upper body in the frontal plane during the MSLS to prevent a lateral pelvic drop toward the trail leg. The greater recruitment of the gluteus medius found during the MSLS may have also occurred to control the higher knee valgum. Although non-weight-bearing exercises can be used to strengthen the hip abductors, different neuromuscular patterns are likely used during weight-bearing activities. Bolgla and Uhl[28] found that unloaded, weight-bearing pelvic-drop exercises with hip abduction of the free leg produced higher hip-abductor EMG in the stance leg than non-weight-bearing hip-abduction exercises. According to DiMattia et al,[29] there was a low correlation ($r = .2$) between non-weight-bearing, isometric hip-abduction strength and the maximal dynamic hip-adduction angle during the unloaded SLS. Thus, non-weight-bearing exercises may not best condition the lower body for high-demanding weight-bearing activities. Our findings are in agreement with these studies that show weight-bearing, multijoint exercises performed primarily on a single leg produce high activation of the gluteus medius.

Research is conclusive that the gluteus medius is recruited during the unloaded SLS[10]; however, improved strength may be limited by the inability to add resistance because of the high demand to stabilize the resistance using 1 foot as the base of support. In addition, higher loads and relative intensity may be required during training of the hip abductors to provide the necessary joint stabilization during high forces encountered during landing and sport maneuvers. Eighty-five percent of the subjects' 3RM was completed with each exercise, which is an intensity typically prescribed to increase strength. The MSLS is an exercise of moderate stability that allows relatively high loads to be lifted in comparison with loads that can be lifted during the SLS.

Clinical Implications

In a previous study, Behm et al[5] suggested that moderately unstable resistance exercises may be optimal to improve both joint stabilization and strength. In our study, the MSLS was performed on a stable platform with less base of support than the TLS to provide a moderately unstable exercise. Performing weight-bearing exercises similar to the MSLS may best achieve specificity because most sport and daily activities are performed in a partial or complete unilateral condition.

Research has indicated that hip-abduction weakness and fatigue are associated with increased knee-valgum angle and higher incidence of iliotibial-band syndrome and patellofemoral pain.[4,30–33] Studies have shown that females demonstrate higher knee valgum during an SLS[34] and single-leg landings, which is suggested to be a mechanism for knee injury.[35] As a result of these previous findings, improving hip abduction[35] and hamstring strength[36] has been suggested to improve knee-joint kinematics. A previous study reported significant squat strength improvement after MSLS and TLS training in a group of untrained males, but strength differences were not found between the 2 types of training.[6] Further strength-training studies are necessary to evaluate the effectiveness of the MSLS with female athletes. Female athletes may best benefit from MSLS training based on the activation patterns found in our study.

During a rehabilitation program the MSLS may be included after beginning the weight-bearing exercises with the more stable TLS and before the more difficult SLS. Initially, body weight can be used for resistance before progressing from dumbbells to a loaded barbell as strength improves. The MSLS is similar to the lunge performed without a step and eliminates the landing phase during the step. These exercises may be performed at the appropriate stage of rehabilitation when weight can be added to the body while minimizing stress on the knee by eliminating the step and allowing most higher loads to be placed on the lead leg. When maximizing strength improvement is the goal for athletes training with the MSLS, heavy loads, similar to the intensities used to produce increased strength on the TLS, can be prescribed.[6]

Limitations

The results of this study are limited to trained female athletes, so results may differ with other populations. The subjects were allowed to perform the TLS at their natural pace while the MSLS rear- and lead-leg positions were primarily subjectively controlled to simulate joint positions that occurred during the TLS. The data are limited to this technique and may differ with variations in speed, acceleration, and anteroposterior knee translation. The results are limited to the activation of the biceps femoris, rectus femoris, and gluteus medius. The EMG data collected did not provide a separate analysis of the ascent and descent phases of the exercises and were not synchronized with the video. Thus, muscle activation was not analyzed at definitive positions during the exercises.

Conclusion

Based on results from our study, the MSLS produced higher biceps femoris and gluteus medius activity, and the TLS produced higher rectus femoris activity. The greater knee-valgus angle found during the MSLS may demonstrate the need for greater hamstring and hip-abductor activity to control the position of the knee. Although squat strength gains are shown to occur with both exercises, the higher Q:H EMG ratio produced by the TLS may imply creating or maintaining a muscle imbalance at the knee after training. With production of a lower Q:H EMG ratio, the results of our study indicated that the MSLS could be implemented in a strength-training program to maintain the muscle-strength balance at the knee.

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