
Objective: To determine differences in strength and range of motion (ROM) between participants who exhibit medial knee displacement (MKD) during a squat that is corrected by a heel lift and those who do not.

Design: Case control.

Setting: Sports medicine research laboratory.

Participants: Thirty-seven healthy subjects (control, 19; MKD, 18) with no lower-extremity injury in the past 6 months volunteered to participate.

Interventions: Not applicable.

Main Outcome Measures: Peak force was measured in newtons using a hand-held dynamometer and passive ROM was measured in degrees with a goniometer. Separate multivariate analyses of variance were used to determine differences in strength and ROM between groups. Post hoc testing was used to elucidate differences between groups.

Results: The MKD group had the following: greater hip external rotation strength ($P=0.03$), increased hip extension strength ($P=0.01$), less plantarflexion strength ($P=0.007$), and increased hip external rotation ROM ($P=0.008$).

Conclusions: The MKD group exhibited tight and weak ankle musculature. Interventions focusing on improving strength and ROM of the ankle may improve kinematics during a squat.

Key Words: Knee; Muscle, skeletal; Range of motion, articular; Rehabilitation.

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DYNAMIC KNEE VALGUS motion is described to result from the combination of femoral adduction and internal rotation as well as tibial abduction and external rotation during squatting or jump-landing maneuvers. Cadaver studies have shown that knee valgus increases the load on the ACL especially in combination with tibial internal rotation. Thus, dynamic knee valgus motion is often theorized as a risk factor for acute knee injuries, such as noncontact ACL injury. Preliminary evidence for knee valgus motion as an ACL injury risk factor has been shown by Hewett et al in a prospective cohort study involving 8 ACL injuries. Mounting evidence suggests that limiting knee valgus by maintaining proper alignment during activity may prevent ACL injury.

Movements associated with dynamic knee valgus are also theorized to play a role in chronic knee injury, especially PFPS, by altering the compressive forces during movement. Lee et al reported that greater than 30° of femoral internal rotation causes a significant increase in patellofemoral joint contact pressures. Additionally, tibial internal rotation has also been reported to cause increase in patellofemoral joint contact pressures along the lateral patellar facet. Huberti and Hayes observed a 10° shift in Q-angle increased the peak patellofemoral contact forces by 45%. Increased contact forces due to movements comprising dynamic knee valgus may lead to chondral degeneration and patellofemoral pain symptoms. Given the potential for dynamic knee valgus motions to influence ACL injury and patellofemoral pain risk it is important to understand factors that may contribute to dynamic knee valgus motion.

Clinical observation of dynamic knee valgus motion is performed by noting for excessive medial displacement of the knee by identifying if the center of the patella moves medially and crosses over a line extending upward from the great toe during a squating maneuver. Presence of excessive MKD is believed to be influenced by specific strength and flexibility deficits of hip and ankle joint musculature. Specifically, hip muscle imbalances consisting of hip external rotator and abductor weakness may allow for increased hip internal rotation and adduction motion. Also, tightness of the hip adductor and internal rotator musculature may cause internal hip adduction and internal rotation moments and facilitate hip adduction and internal rotation motion to occur. The movements of hip adduction and internal rotation during a weight-bearing task may allow for excessive MKD and dynamic knee valgus alignment. Lower-leg muscle imbalances involving tightness of lateral ankle musculature, such as the lateral gastrocnemius and soleus, and peroneals may contribute to tibial abduction and external rotation, thus facilitating excessive MKD and dynamic knee valgus alignment. Weakness of the medial gastrocnemius, anterior tibialis, and posterior tibialis may decrease the ability to control knee valgus and foot pronation motions and also contribute to excessive MKD and dynamic knee valgus positioning. However, research has not investigated the relative contributions of hip and ankle muscle strength and flexibility on excessive MKD.

List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACL</td>
<td>anterior cruciate ligament</td>
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<tr>
<td>ASIS</td>
<td>anterior superior iliac spine</td>
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<tr>
<td>CI</td>
<td>confidence interval</td>
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<tr>
<td>ICC</td>
<td>intraclass correlation coefficient</td>
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<tr>
<td>MANOVA</td>
<td>multivariate analysis of variance</td>
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<td>MKD</td>
<td>medial knee displacement</td>
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<td>PFPS</td>
<td>patellofemoral pain syndrome</td>
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<td>ROM</td>
<td>range of motion</td>
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<td>SEM</td>
<td>standard error of the mean</td>
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Heel lifts are used by clinicians to differentiate between lower-leg and hip muscle imbalances as the primary contributing factors to excessive MKD and dynamic knee valgus positioning. It is stated that lower-leg muscle imbalances may be the primary cause of MKD if MKD is no longer present after placing a heel lift under the calcaneus during a double-leg squat. However, hip muscle imbalances may be the primary cause if MKD is still present during the double leg squat even after placement of the heel lift. Correction of MKD when using a 5.1-cm (2-in) heel lift is theorized to occur by increasing ankle plantarflexion and thereby decrease the tension within the lateral ankle musculature and restore the normal length-tension relationship of the medial gastrocnemius, anterior tibialis, and posterior tibialis so that they may better control knee valgus and foot pronation. We are unaware of any research that has assessed whether there are lower-leg strength and flexibility deficits in those people who show MKD without a heel lift, but show no MKD when using a heel lift.

Evaluating the influence of hip and lower-leg strength and flexibility on MKD may assist in gaining an improved understanding of factors that contribute to the risk of ACL injury and PFPS. Furthermore, understanding the contributions of hip and lower-leg muscle strength and flexibility to MKD is required for the development of effective prevention and rehabilitation programs for ACL injury and PFPS. Therefore, the purpose of this study was to compare the strength and ROM of the hip and lower leg in control subjects who do not show excessive MKD during a double-leg squat with that of subjects who visually exhibit excessive MKD during a double-leg squat that is corrected by a heel lift (MKD). We hypothesized that the MKD group would show significant differences in select hip and ankle muscle strength and flexibility measures when compared with the control group.

**METHODS**

**Participants**

We screened 75 participants for MKD. Nineteen participants (4 men, 15 women) qualified for the control group and 18 participants (3 men, 15 women) met the criteria for the MKD group (see table 1 for descriptive information). We operationally defined a participant as having excessive MKD if the midpoint of the patella passed medial to the great toe. Control participants did not have MKD during a squat and knees stayed directly over their toes. Additionally, subjects were between 18 and 25 years of age, had no history of lower-extremity surgery within the past year, and had no lower-extremity injury within the past 3 months. All enrolled subjects completed the protocol.

**Procedures**

All testing was performed at the Sports Medicine Research Laboratory at the University of North Carolina. Prior to testing, participants completed an informed consent form approved by the Institutional Review Board at the University of North Carolina and underwent a postural screening to assess for the presence of MKD. The overhead squat test was performed prior to testing to identify those people who displayed excessive MKD and those who did not display excessive MKD. Each participant performed a series of double-leg squats (5 repetitions) in a standardized position: feet shoulder width apart, toes pointing forward, and hands above their head. Participants were then instructed to squat as if they were sitting in a chair. Participants were videotaped performing the overhead squat test while the principal investigator observed the participant. Participants qualified for the MKD group if they had excessive MKD in the dominant leg during the overhead squat test that was corrected when the squat test was performed on a heel lift (figs 1B, 1C). Participants qualified for the control group if no MKD was present during the overhead squat test.

<table>
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<td>Variables</td>
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<td>Height (cm)</td>
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<td>Mass (kg)</td>
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<td>Age (y)</td>
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NOTE: Values are group mean ± SD.
(fig 1A). Participants who met the MKD criteria were scheduled to return for testing within 1 week of the screening process. Participants were re-screened prior to testing to verify that they still met the group inclusion criteria. Control group participants were matched to MKD group on the basis of sex, age, height, and weight. Previously published research from our laboratory has identified the overhead squat test as a reliable tool to identify faulty movement patterns (κ range, 0.75–1.00).14

Prior to testing each participant was allowed to warm up on a stationary bicycle at a self-selected pace for a maximum of 5 minutes. All testing was performed on the participants’ dominant leg, which was operationally defined as the leg used to kick a ball for maximal distance.

Range of motion. We assessed passive ROM of the hip and ankle in a counterbalanced order using a standard 30.5-cm (12-in) plastic goniometer and using methods similar to Norkin and White.18 The principal investigator made all ROM measurements. Three trials were taken of each motion tested and the mean value was calculated and used for analyses. The intrarater reliability for the primary investigator for all ROM measurements was excellent (ICC 3,1 range, .87–.96; SEM range, 1.61°–2.59°).

Ankle dorsiflexion ROM was assessed with the knee both extended and flexed to better isolate gastrocnemius and soleus muscle flexibility, respectively. Ankle dorsiflexion ROM with the knee extended was assessed with the participant in a supine position with a foam roller under the distal shank to maintain full knee extension. Ankle dorsiflexion ROM with the knee flexed was assessed in the same position except that the foam roller was under the knee and the foot was allowed to hang off the end of the plinth. The use of the foam roller allowed the knee to maintain a position of 30° of flexion. For both assessments the stationary arm of the goniometer was aligned with the fibula and the mobile arm was aligned with the fifth metatarsal. The investigator took the foot through the ROM until resistance was felt and the measurement was recorded.

We assessed hip abduction ROM with the participant in a supine position. The dominant leg was passively abducted while palpating the opposite ASIS. Inferior movement of the ASIS indicated that the hip abductors were pulling and rotating the pelvis and signified the point when measurements were made. The axis of the goniometer was placed over the dominant leg ASIS, the stationary arm in line with opposite ASIS, and the mobile arm aligned with the shaft of the femur.

Hip external rotation ROM was assessed with the subject in a supine position and the hip and knee flexed to 90°. The leg was externally rotated until soft tissue resistance was felt by the primary investigator. The axis of the goniometer was placed in line with the long axis of the femur, the stationary arm in line with long axis of the body, and the mobile arm aligned with the shaft of the tibia.

Strength. We measured isometric strength of the subject’s dominant leg for the following joint motions: ankle plantarflexion, ankle dorsiflexion, hip abduction, hip extension, hip internal rotation, and hip external rotation. A hand-held dynamometer6 was used to assess strength measurements. Peak force was recorded in newtons for 3 separate trials that each lasted 5 seconds. The mean of these measures was calculated for each of the muscles tested and used for analyses. A 30-second rest interval was allowed between each trial to minimize fatigue. Participants performed 1 submaximal practice trial for each strength test prior to testing to familiarize themselves with the testing procedures. The primary investigator performed all strength measurements and the order of testing was counterbalanced. Strength assessments were assessed via active resistance tests rather than break tests. Subject positioning for the strength tests are similar to those reported by Kendall et al.19 except that we performed hip internal and external rotation tests in a prone position with the hip flexed to 0°. Subject positioning during hip internal rotation, hip external rotation, and hip extension muscle strength assessment were all performed in a prone position with the knee of the test leg flexed to 90°. Straps secured the participant to the plinth and the dynamometer was placed at the lateral and medial malleolus for internal and external rotation, respectively. Subjects were instructed not to flex or extend their knee during the test. Hip extension strength was assessed with the dynamometer placed over the posterior aspect of the subject’s thigh, just proximal to the knee joint line. The subject was instructed to maintain the flexed knee position during testing. Hip abduction strength assessment was performed with the subject in a side-lying position on the side of their nondominant leg. The subject abducted the hip of the dominant leg until it was parallel with the testing table. A neutral hip rotation position was maintained during testing. The dynamometer was positioned just over the lateral aspect of the knee, just proximal to the knee joint line. Hip adduction strength was assessed with the subject side-lying and dynamometer placed proximal to the medial knee joint line above the epicondyle. Ankle plantarflexion and dorsiflexion strength were assessed in the sitting position with the legs extended out in front of the subject and hands across the chest. The dynamometer strap was placed at the metatarsals heads. The intrarater reliability ranged from good to excellent for each of the strength measures (ICC range, .73–.93; SEM range, 8–22N).

Data Reduction

We normalized the force output of each subject using methods previously reported by Jaric.20 This procedure normalizes muscle force measured by a dynamometer and takes into account variation in muscle cross-sectional area as a function of body mass. This method is thought to be a more appropriate normalization method because recorded force is proportional to muscle force even though limb leverage does not change. The equation used for normalization in this study was $S_n = S/m$, where $S_n$ is the normalized strength value, $S$ is the force (in newtons) measured by the dynamometer, and $m$ is body mass (in kilograms).

Statistical Analysis

Separate MANOVA tests were performed for ROM and strength data. Each MANOVA consisted of 1 between (group: control vs MKD), and 1 within factor for each analysis (ROM: ankle dorsiflexion with knee straight, ankle dorsiflexion with knee bent, hip external rotation, hip abduction; strength: hip internal rotation, hip external rotation, hip extension, hip abduction, hip adduction, ankle plantarflexion, ankle dorsiflexion strength). One-way analyses of variance were performed as a post hoc test to identify where specific differences occurred after a significant group effect was found for the MANOVA. Independent $t$ tests were used to determine differences in descriptive data including height, weight, and age. Statistical significance was set a priori at $\alpha$ equal to .05 or less and the statistical package for the social sciences was used for all analyses.

RESULTS

There were no significant differences observed between groups in average height ($P = .92$), weight ($P = .78$), and age ($P = .17$) (see table 1). The MANOVA revealed significant
differs between groups for both strength (F1,29 = 5.53, P < .001) and ROM (F4,32 = 3.31, P = .02). Observed power and effect size values for each variable of interest are reported in tables 2 and 3. These findings indicate that there were significant differences in select strength and ROM variables between the excessive MKD and control groups.

The MKD group showed greater hip external rotation ROM (F1,35 = 8.05, P = .008) and tended to have decreased ankle dorsiflexion–knee flexed ROM compared with controls (F1,35 = 3.62, P = .06) (see table 3). These findings support our original hypotheses. There were no significant differences between groups for hip abduction ROM (F1,35 = 1.67, P = .21) or ankle dorsiflexion–knee straight ROM (F1,35 = 1.52, P = .23).

There were also significant differences between groups for hip extension strength (F1,35 = 7.21, P = .01) and hip external rotation strength (F1,35 = 5.17, P = .03). Contrary to our original hypothesis, the MKD group showed greater strength for both hip extension and external rotation values (see table 2). There was a trend toward increased hip adduction strength in the MKD group compared with the control group (F1,35 = 3.60, P = .06); however, this difference was not statistically significant. In support of our original hypothesis, plantarflexion strength was decreased in the MKD group compared with control (F1,35 = 8.37, P = .007). There were no differences in strength between groups for hip abduction (F1,35 = 1.66, P = .21), hip internal rotation (F1,35 = 0.4, P = .85), and dorsiflexion (F1,35 = 0.47, P = .50) values.

**DISCUSSION**

Our investigation compared strength and ROM of hip and ankle musculature in participants who presented with excessive MKD during an overhead squat that was corrected when using a heel lift (MKD group) with that of participants who did not show MKD (control group). We found that the MKD group showed significant differences in ankle and hip muscle strength, as well as hip ROM, when compared with the control group. Specifically, the MKD group exhibited less plantarflexion strength and greater hip extension, hip external rotation strength, and hip external ROM compared with the control group. The MKD group tended to display less ankle dorsiflexion–knee flexed ROM and greater hip adductor strength, but these differences were not statistically significant.

Our most important finding was decreased plantarflexion strength in the MKD group. Lloyd and Buchanan found that the medial gastrocnemius acts as a dynamic knee stabilizer and offsets knee valgus moment. Thus, MKD may be a result of decreased plantarflexion strength, specifically the medial head of the gastrocnemius. We tested plantarflexion strength with the knee extended, which would have significant gastrocnemius involvement. We observed a 17% decrease in plantarflexion strength in the MKD group when compared with the control group. Additionally, the 95% CIs do not overlap, indicating that the 2 groups are distinctly different. Based on these findings, we believe that medial gastrocnemius weakness may play an important role in facilitating MKD.

Hip muscle weakness and tightness did not appear to be a factor contributing to excessive MKD. To our surprise, people who showed excessive MKD possessed greater hip external rotation and hip extension strength. Also, there were no differences in hip abduction or hip adduction strength between these groups. These findings suggest that weakness of the hip external rotators, gluteus maximus, and gluteus medius were not key factors contributing to excessive MKD in the subjects of this study. Hip muscle tightness also did not appear to have been a major factor because subjects with excessive MKD showed greater hip external rotation ROM and did not display less ROM on any of the other hip motions tested. It is possible that our participants with MKD may have adequate hip strength but not effectively activate musculature during the squat to prevent MKD. Further research is needed to assess muscle activation levels during the squat to determine if MKD is associated with muscle strength or activation levels.

We originally hypothesized that the MKD group would show decreased dorsiflexion–knee extended and dorsiflexion–knee flexed ROM, representing decreased gastrocnemius and soleus muscle flexibility. Tightness of these muscles would result in greater passive muscle tension that may facilitate larger knee valgus moments and lead to MKD. However, there were no statistically significant differences in dorsiflexion ROM measures. Although not statistically significant, subjects with excessive

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**Table 2: Normalized Peak Isometric Strength Values Between Groups**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control</th>
<th>Medial Knee Displacement</th>
<th>P</th>
<th>Effect Size Partial η²</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip extension</td>
<td>16.4±3.6 (14.8–18.0)</td>
<td>19.5±3.3 (17.8–21.2)</td>
<td>.01*</td>
<td>.17</td>
<td>.74</td>
</tr>
<tr>
<td>Hip abduction</td>
<td>16.9±4.7 (15.2–18.7)</td>
<td>18.5±2.2 (16.7–20.3)</td>
<td>.21</td>
<td>.05</td>
<td>.24</td>
</tr>
<tr>
<td>Hip adduction</td>
<td>16.4±3.0 (15.1–17.7)</td>
<td>18.2±2.6 (16.8–19.5)</td>
<td>.06</td>
<td>.09</td>
<td>.46</td>
</tr>
<tr>
<td>Hip internal rotation</td>
<td>5.9±1.7 (5.3–6.7)</td>
<td>5.9±1.3 (5.2–6.6)</td>
<td>.88</td>
<td>.001</td>
<td>.05</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>12.5±2.2 (11.8–13.5)</td>
<td>14.1±1.9 (13.1–15.1)</td>
<td>.03*</td>
<td>.13</td>
<td>.59</td>
</tr>
<tr>
<td>Ankle dorsiflexion</td>
<td>16.7±2.0 (15.8–17.5)</td>
<td>17.1±1.7 (16.2–18.0)</td>
<td>.50</td>
<td>.01</td>
<td>.10</td>
</tr>
<tr>
<td>Ankle plantarflexion</td>
<td>15.8±3.0 (14.5–17.1)</td>
<td>13.1±2.6 (11.8–14.4)</td>
<td>.007*</td>
<td>.19</td>
<td>.80</td>
</tr>
</tbody>
</table>

*Significantly different between groups.

**Table 3: ROM Values Between Groups**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control</th>
<th>MKD</th>
<th>P</th>
<th>Effect Size Partial η²</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip abduction</td>
<td>39.2±5.4 (36.6–41.7)</td>
<td>41.5±5.7 (38.6–44.2)</td>
<td>.21</td>
<td>.05</td>
<td>.24</td>
</tr>
<tr>
<td>Hip external rotation</td>
<td>51.9±10.9 (47.2–56.6)</td>
<td>61.3±9.0 (56.5–66.1)</td>
<td>.008*</td>
<td>.19</td>
<td>.79</td>
</tr>
<tr>
<td>Dorsiflexion: knee straight</td>
<td>10.7±6.7 (8.1–13.4)</td>
<td>8.5±4.2 (5.8–11.2)</td>
<td>.23</td>
<td>.04</td>
<td>.22</td>
</tr>
<tr>
<td>Dorsiflexion: knee flexed</td>
<td>19.5±8.4 (16.3–22.6)</td>
<td>15.3±4.3 (12.0–18.5)</td>
<td>.06</td>
<td>.09</td>
<td>.46</td>
</tr>
</tbody>
</table>

NOTE. Values are mean degrees ± SD (95% CI). *Significantly different between groups at P = .05.
MKD displayed approximately 20% less dorsiflexion ROM with the knee flexed (control, 19.5°; MKD, 15.3°; \( P = .06; 21.5\% \) difference) and extended (control, 10.7°; MKD, 8.5°; \( P = .23; 20.5\% \) difference). In particular, the magnitude of difference between dorsiflexion–knee flexed ROM measures may be clinically significant when examining the 95% CI associated with these data (see table 3). The 95% CIs for dorsiflexion–knee flexed ROM overlapped less than 2°. Although this difference is not statistically significant, we believe the differences are clinically meaningful and warrant further investigation. In addition, our results mirror those of Vesci et al21 from a national scientific meeting that compared participants with visible knee valgus versus those with no knee valgus and observed a 25% reduction in passive ROM of the gastrocnemius muscle in subjects with MKD. The role of ankle dorsiflexion ROM affecting lower-extremity kinematics should not be discounted and more research is needed to better understand the influence of limited dorsiflexion ROM on knee valgus position.

Previous research has investigated the relationship between hip strength and knee frontal plane motion. Several authors have identified correlations between knee frontal plane motion and hip strength including hip external rotation,16 hip abduction,16 knee flexion,16 and knee extension strength.16 These studies indicate that weakness of the muscles responsible for these motions result in greater frontal plane motion. Our findings do not agree with these previous studies because we actually observed greater hip extension and hip external rotation strength and hip external rotation ROM in subjects showing MKD. We believe that this further supports the ability of the heel lift to discriminate between hip and lower leg muscle imbalances. Our study is the first known to differentiate the source of MKD and our results suggest that hip weakness was not an issue and is most likely due to our inclusion criteria. Additionally, previous research used a single-leg squat instead of a double-leg squat, which may require greater hip muscle control and partially explain differences in our findings. To our knowledge, no research has examined the role of hip flexibility, knee flexion, knee extension, and hip external rotation ROM in subjects showing MKD. We believe that this further supports the ability of the heel lift to discriminate between hip and lower leg muscle imbalances. Our study is the first known to differentiate the source of MKD and our results suggest that hip weakness was not an issue and is most likely due to our inclusion criteria.

We used visual identification of medial knee displacement for 2 reasons: (1) it is a method commonly used in a clinical setting and (2) clinicians may not have access to kinematic analysis. Clinicians need an efficient and easy way to identify faulty movement patterns such as knee valgus or MKD. We decided to use objective visual criteria because it can be done on a daily basis by clinicians with little or no equipment. It can be difficult for clinicians to agree on movement quality during lower-extremity tasks when they are given general guidelines.22 To avoid this potential problem we strictly defined our inclusion criteria (mid-patella moving medial to the great toe) and used a categorical yes-no grading system indicating if a condition was present or not. To avoid further confusion, if an investigator considered a subject questionable on meeting the inclusion criteria, the subject was excluded from the MKD group. We believe this increased group homogeneity.

Study Limitations

Our study is not without limitations. Investigators were not blinded to the subject’s group assignment. This may have unintentionally caused bias on the part of the tester when measuring strength and ROM. This is less of an issue with strength because testing was performed using a maximal voluntary contraction. Another limitation is that we used specific criteria to assign groups, so our results may only be applicable to people meeting those criteria rather than to the general population. It is also possible that our 2 groups had different foot types, such as pes planus or pes cavus, which resulted in excessive MKD. Because we did not assess foot type as a variable, we did not feel discussion would be appropriate. Additionally, we are not aware of any research that correlates dorsiflexion ROM or ankle strength with foot type. We did not control for activity level between groups because we intend the overhead squat test to be applicable to all populations with different levels of athletic background. Future research should consider foot type and athletic background. Strength was assessed using an isometric contraction and handheld dynamometry. Further research should use isokinetics to determine if these relationships still exist. Finally, muscle activation patterns should be identified via electromyography to determine their influence on lower-extremity alignment during functional activities.

CONCLUSIONS

Decreased plantarflexion weakness, possibly from the medial head of the gastrocnemius, seems to be an important contributing factor to MKD. Also, the trend toward decreased ankle dorsiflexion ROM with knee flexed suggests that soleus muscle tightness may also be a factor to consider in future research. Hip muscle imbalances do not appear to be major factors contributing to MKD in subjects who display MKD without a heel lift, but do not show MKD with a heel lift in place. This evidence suggests that there may be different factors contributing to MKD and knee valgus at the knee and hip. Clinicians should consider trying to distinguish the potential cause of MKD when attempting to correct MKD and knee valgus motion.

References


Suppliers
a. Chatillon CDS 300; Ametek, 8600 Somerset Dr, Largo, FL 33773.
b. Version 14.0; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.