INFLUENCE OF PISTOL SQUAT ON DECLINE ANGLE AND HAMSTRING MUSCLE ACTIVITY IN A HEALTHY POPULATION

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Keywords: Pistol squat, Optimal decline angle, Muscle activity, pistol squat training, Electromyography.

Abstract:

Background: Modern lifestyle and physically inactive society is one of the most common causes of the reduced knee joint mobility. Underactive and uneven distribution of stresses on the knee joint is one the main causes for decreased joint stability and flexibility.

Aim: The purpose of the study is to know the Influence of pistol squat over decline angle and Hamstring muscle activity of healthy population.

Methodology: It is a Quasi Experimental Study design, of about 20 subjects aged 18 to 25 years and both male and female healthy population were included in the study. Ordinal scale was used to assess the Decline angle of knee range of motion. Subjects were asked to perform pistol squat and the muscle activity of Hamstring was analyzed through Electromyography and 6 weeks Pistol squat protocol training was given. Then, the pre-test and post-test values were compared by using paired sample t test and Chi square test.

Results: Shows that there is a significant change in Muscle activity (significant increase) and Decline angle (significant increase) from Pre to post test. There is a significant change in ordinal scale value from pre to post. Significant change in scores from Very poor to Poor, Poor to Normal, Normal to Optimal ordinal scores.

Conclusion: In this study the squatting activity had a significant effect on the flexibility of hamstrings and increased muscle activity as well as achieved the optimal decline angle of knee joint improved on the healthy population.

Introduction

To maintain good physical health, seeking guidance from a physiotherapist is greatly essential. A sedentary lifestyle is one of the major causes of prolonged immobility in people that extends the period of sitting, leading to muscle tightness, mainly in the lower limbs and at the back of the thighs. This makes it more difficult to move with ease during day to day activities and can increase susceptibility to musculoskeletal injury. Due to a lack of appropriate postural education, we are prone to postural deficits that affect our biomechanics.

Maintaining good postural exercise prevents further abnormal adaptation of posture in the gluteal amnesia with regression in hamstring flexibility. This affects the knee joint by inappropriate weight bearing. Pistol squats are difficult but an equally rewarding bodyweight exercise. Pistol squats are a great unilateral exercise that require strength, stability, flexibility and mobility. They also which demand significant balance, joint stability, muscle activation and body control along with body awareness, which is defined as the internal understanding of where the body is in space. This further helps avoid potential injury.
The dominant side will always exhibit good balance, but perfect symmetry cannot be achieved. Pistol squats are one of the ideal methods for addressing imbalance. The benefits of the pistol squat are isolation of each leg for balancing strength deficits, muscle recruitment, while improving posterior chain strength, increasing general flexibility and mobility as well as stability, and improving proprioception though the leg and core. It plays a vital role for maintaining a normal gait pattern. By implementing a proper pistol squat protocol, an optimal decline angle as well as lower limb flexibility can be achieved.

The pistol squat is predominately a knee flexion and extension movement, where the quadriceps is involved in the eccentric (flexion) and concentric (extension) exercise. The quadriceps provides control and power for the lower limbs.

With the pistol squat, core stabilizers allow power to shift from the lower to the upper body, and to resist rotational forces on the spine during descent. During the pistol squat, the hamstrings stabilize and control the eccentric part of the movement, which is vital for lockout (hip extension) and supporting the knee and hip joints during the entire action.

Purdam et al. (2003) noted that further assessment of eccentric exercises is essential for further validation of these single limb squat exercises [1]. In particular, it was identified that biomechanical tests of flat and decline squats are essential.

Therefore, the aim of the current study is to investigate the biomechanical effects and muscular involvement when performing squats at different decline angles and to discuss the implications for different rehabilitation protocols; the hypothesis being that there is a biomechanically optimum angle for squat decline in knee rehabilitation.

Khan et al. explained that although they appear to have a clinical effect, many eccentric exercises and techniques employed have little scientific background to support their use [2].

Jim Richards et al. (2016) identified that the activity of the hamstring muscles, especially of the biceps femoris, increased as the decline angle increased above 15 degrees [3]. The action of biceps femoris stabilizes the knee against anterior displacement of the femur on the tibia. These findings would suggest that there is little benefit of using a decline angle greater than 15-20 degrees unless the purpose is to offer an additional stability challenge to the knee joint.

In this study, electromyographic examination is performed with regard to the hamstring muscles during the pistol squat.

Kiran Mendhe et al. (2017) observed that a single-leg squat improves the flexibility of the hamstring and lower back muscles [4]. In young adults, for whom tightness is a common factor because of maintaining a sedentary lifestyle, single-leg squatting activity can be recommended to maintain flexibility.

Purdam et al. further examined eccentric exercise, noting that it is essential for more validation of these single-limb squat exercises. Moreover, in many studies, the effectiveness of decline squats as a rehabilitative tool has been verified.

The double-leg squat was first reported as part of closed-chain knee rehabilitation in the 1990s [5]. The double-leg squat progressed into a single leg-squat as part of exercise progression. The first paper describing the single-leg squat was published by Chris Benn, a student physical therapist at the University of Rhode Island, United States of America, in 1988 [6]. The Pistol Squat, also known as the single-leg or one-legged squat, is an advanced bodyweight exercise in which the squat is performed using only one leg.

The angle created by a descending line or plane with a horizontal plane is called the decline angle. The decline angle increases knee flexion and promotes flexibility of the muscles as well as joint range of motion.

The objective of the study is to investigate muscle activity of the pistol squat during decline by using electromyography and to improve the optimal decline angle.

To improve decline of the knee, more flexibility and stability are given to the joint and muscle imbalance is corrected.

In this study, the test was performed by using surface electromyography to examine hamstring muscle activity.

In this trial, focus was more on the hamstring muscle because the majority of knee joint problem arise due to hamstring weakness and instability of the knee joints.

How far knee flexion can occur in a closed kinetic chain without any musculoskeletal dysfunction during the pistol squat, and then how efficiently hamstring muscles undergo the eccentric load, will be discussed in this study.

**Research Objective**

The aim of the study was to evaluate the influence of pistol squat on decline angle and muscle activity of the lower limbs, as well as rehabilitation of the hamstring muscle.

**Need for the Study**

There are so many studies related to single-leg squat tested globally, however, to date, there is not even a single study regarding the pistol squat.

Thus, the following justifications for performing the study can be given:

- To increase single-leg strength and balance.
- To improve movement mechanics of the lower body.
- To isolate each leg for balancing strength deficits, which plays a vital role on full movements of muscle recruitment as well as equal distribution of weight-loading.
- To achieve adequate knee flexion range and muscle control.

Hypotheses

NULL HYPOTHESIS:
There will be no significant improvement in pistol squat with regard to decline angle and muscle activity in adults.

ALTERNATIVE HYPOTHESIS:
There will be significant improvement in pistol squat with regard to decline angle and muscle activity in adults.

REVIEW OF LITERATURE

Kiran Mendhe, et al. 2017 (Effect of single leg squatting on sit and reach test in normal individuals) [4]. It was concluded that single-leg squatting improved flexibility of the hamstring and lower back muscles.

- J. Zwerver, et l. (2007) (Biomechanical analysis of the single-leg decline squat). It was concluded that all single-leg squats performed at a decline angle >15degree increase patellofemoral force [5].
- Jim Richards, et al. (2008) (A biomechanical investigation of a single-limb squat: implications for lower extremity rehabilitation exercise). It was concluded that as the decline angle increases, the ankle plantar flexors decreased [6].
- Sean A. Horan, et al. (2014) (Lower-Limb Kinematics of Single-Leg Squat Performance in Young Adults). It was concluded that poorly executed single-limb squat performance is characterised by inadequate knee flexion and excessive frontal plane motion of the knee and hip [7].
- Khan KM, et al. (1998) (Patellar tendinopathy: some aspects of basic science and clinical management). It was concluded that the applied strengthening programme emphasises functional exercises, including eccentric training effects on squat [8].
- GK Fitzgerald, et al. (1997) (Open versus closed kinetic chain exercise: issues in rehabilitation after anterior cruciate ligament reconstructive surgery). It was concluded that closedKinetic chain exercises provide more flexibility to the hamstring muscle [9].
- Roland van den Tillaar, et al. (2018) (COMPARISON OF BILATERAL AND UNILATERAL SQUAT EXERCISES ON BARBELL KINEMATICS AND MUSCLE ACTIVATION.). It was concluded that performing unilateral squats with the foot forward results in significantly greater activation of the semitendinosus and reduced activation of the other quadriceps muscles [10].
- Jim Richards, et al., 2016 (The effect of different decline angles on the biomechanics of double limb squats and the implications to clinical and training practice). It was concluded that squat decline angle offers knee rehabilitation that allows a gradual increase in the load applied on the knee as well as a gradual reduction in ankle moments and forces as the decline angle increases with an optimum angle of between 15-20 degrees, which is less than the decline angles previously used in rehabilitation [12].
- Anne Khuu, et al. (2016) (NOT ALL SINGLE LEG SQUATS ARE EQUAL: A BIOMECHANICAL COMPARISON OF THREE VARIATIONS). It was concluded that the mechanics of the trunk, pelvis and lower extremity during the SLS were affected by the position of the non-stance leg in healthy females. Practitioners can use these findings to distinguish between SLS variations and to select the appropriate SLS for assessment and rehabilitation [13].
- Samuel J. Dawson, et al. 2015 (Improving Single-Legged Squat Performance: Comparing 2 Training Methods With Potential Implications for Injury Prevention). It was concluded that a 6-week intervention of either hip-strengthening or skill-acquisition training improved lower limb biomechanics [14].
- Xavier Valle, et al. (2015) (Hamstring Muscle Injuries, a Rehabilitation Protocol Purpose). It was concluded that exercises in open- and closed-kinetic chains for hip extension and knee flexion, overlapping strength work (isometric, concentric and eccentric) in lengthening positions with a high hip angle, are focused on recovering eccentric strength in all degrees but especially, when strain on the hamstrings is higher [15].
- Benjamin K. Weeks, et al., (2012) (Kinematic predictors of single-leg squat performance: a comparison of experienced physiotherapists and student physiotherapists). It was concluded that physiotherapists and students are both capable of reliable SLS performance assessment. Physiotherapist assessments, however, bear stronger relationships to lower limb kinematics and are more sensitive to hip joint motion than student assessments [16].
- Valdeci Carlos Dionisio, et al., (2013) (Horizontal and Declined Squats in Healthy Individuals: A Study of Kinematic and Muscle Patterns). It was concluded that decline and horizontal plane squats with bipodal support and control of trunk movements in the sagittal plane produce different kinematics (ankle and knee...
joints) but did not modify EMG activity in HP and DP squats, or in descending and ascending phases of the movements [17].

- Pablo Abian, et al., (2020) (Effects of Eccentric Single-Leg Decline Squat Exercise on the Morphological and Structural Properties of the Vastus Lateralis and Patellar Tendon). It was concluded that the SLDSe training carried out with the execution time of 6 s had greater effects on the structural and elastic properties of the PT, and the exercise with the execution time of 3 s caused greater structural adaptations in the VL musculature [18].

- Silvia Gianola, et al., (2017) (Single leg squat performance in physically and non-physically active individuals: a cross-sectional study). It was concluded that physically active individuals seem to be at less risk to perform a non-good SLS while demonstrating greater knee and hip flexion kinematics than non-physically active individuals. Knee flexion can predict SLS performance quality, therefore, greater knee flexion may also be considered a protective element from injuries. [19]

**Methodology**

**STUDY DESIGN:** Quasi experimental design

**STUDY TYPE:** Pre-test/post-test type

**SAMPLE METHOD:** Convenient sampling

**SAMPLE SIZE:** 20 subjects

**STUDY SETTING:** SRM University, SRM Institute of Science and technology

**STUDY DURATION:** 6 weeks

**Inclusion Criteria**

Age 18-25 years

Both men and women were included.

- All participants were free from musculoskeletal impairment.

**Exclusion Criteria**

- Any musculoskeletal or neuromuscular pathologies.
  - Subjects having limb length discrepancies.
- Subjects with low back pain.
- Subjects with any musculoskeletal deformities in the lower limbs.

**Procedure**

The participants were informed about the procedure and the course of the study. Informed consent was obtained who were willing to participate in the study according to the inclusion criteria. The convenient sampling method was used. Instructions are given to participants before pre-test assessment.

During the pre-test, the normal range of motion for the lower limb is evaluated using a goniometer, while muscle girth and limb length measurements are carried out using an inch tape.

To evaluate each subject’s single limb balance, a one repetition maximum of the pistol squat is performed, and the comfortable decline angle for all individuals is assessed.

Before electromyographic evaluation, the investing researcher should give proper instructions to the participants.

Electromyographic activity of the subjects’ limbs during standing is recorded by placing surface electrodes on both legs.

The activity of the hamstring muscle is recored. Prior to electrode attachment, the skin area should be dry shaved, abraded with sandpaper and cleaned. 2, self-adhesive disposable bipolar surface electrodes with an active contact surface of 15 mm and with a 25-mm inter-electrode spacing should be fixed to the skin surface above each muscle.

After the pre-test, the researcher instructs all participants to perform at least 40 repetitions of the pistol squat everyday, for 1 month, after which the post-test is conducted.

Finally, correlating with pre- and post-test data, the conclusions are revealed to the subjects.
Then, the range of knee joint motion is assessed using a goniometer. The steps to use a goniometer are:
- Placement of goniometer:
  1. Align the fulcrum of the device with the fulcrum or the joint to be measured.
  2. Align the stationary arm of the device with the limb being measured.
  3. Hold the arms of the goniometer in place while the joint is moved through its range of motion.
  4. The degree between the endpoints represents the entire range of motion.
- Assessment of knee range of motion (decline angle) is measured in the knee joint.

Knee flexion:
In a standing position, the fixed arm is placed over the distal part of the leg. The moveable arm is placed over the proximal part of the thigh. Then, the fulcrum is the knee joint. To obtain the decline angle, the subjects are asked to descend down with a comfortable range before the post-test.

### Tables 1 and 2:
Assessment of change in muscle activity and decline angle

<table>
<thead>
<tr>
<th>Variable</th>
<th>Timeline</th>
<th>Mean</th>
<th>SD</th>
<th>Std. Error Mean</th>
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<tr>
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<td>Pre</td>
<td>728.44</td>
<td>279.35</td>
<td>62.47</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>735.33</td>
<td>277.80</td>
<td>62.12</td>
</tr>
<tr>
<td>Decline angle</td>
<td>Pre</td>
<td>71.15</td>
<td>8.28</td>
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<tr>
<td></td>
<td>Post</td>
<td>76.70</td>
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<td>2.01</td>
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<table>
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<tr>
<th>Variable</th>
<th>Paired differences</th>
<th>Mean</th>
<th>SD</th>
<th>Std. Error Mean</th>
<th>95% Confidence Interval of the difference</th>
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<th>df</th>
<th>P value</th>
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<td></td>
<td></td>
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<td>SD</td>
<td>Std. Error Mean</td>
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<td>Upper</td>
<td></td>
<td></td>
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<td>9.03</td>
<td>2.02</td>
<td>-11.11</td>
<td>-2.66</td>
<td>-3.41</td>
<td>.003</td>
</tr>
<tr>
<td>Decline angle</td>
<td></td>
<td>-5.55</td>
<td>3.59</td>
<td>0.80</td>
<td>-7.23</td>
<td>-3.87</td>
<td>-6.91</td>
<td>.000</td>
</tr>
</tbody>
</table>

Test: Paired Samples t-test
Inference: The test shows that there is a significant change in muscle activity (significant increase) and decline angle (significant increase) from the pre- to post-test.
Tools Used for Study:
- Goniometer;
- Electromyography;
- Ordinal scale.

Outcome Measures
- Decline angle measured via goniometer;
- Muscle activity measured via electromyography;
- Performance of pistol squat graded in ordinal scale.

DATA ANALYSIS
The collected data were tabulated and analysed using descriptive statistics, while mean and standard deviation were used to assess all the data parameters with the Statistical Package for Social Science (SPSS) version.

Results
Table 1, Graph 1 and Graph 2 demonstrate that total number of participants in this study is 20, the mean muscle activity of the pre- and post-test variables are 728.44 and 735.33, and the mean of decline for the pre- and post-test variables are 71.15 and 76.7, respectively.

Table 2 shows that there is a significant change in muscle activity (significant increase) and decline angle (significant increase) from the pre- to post-test.

Table 3: Assessment of changes in qualitative parameters (ordinal scale) over study period

<table>
<thead>
<tr>
<th></th>
<th>Poor</th>
<th>Post</th>
<th>Chi-square</th>
<th>Total</th>
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</thead>
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<tr>
<td></td>
<td>Normal</td>
<td>Optimal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>Very poor</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Poor</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>

Test: Chi-square test
Inference: There is a significant change in ordinal scale value from pre- to post-test values. Significant changes in the scores from ‘very poor’ to ‘poor’, ‘poor’ to ‘normal’, and ‘normal’ to ‘optimal’ ordinal scores.

Discussion
In this study, the subjects were divided into 2 groups: pre-test and post-test, to determine the influence of the pistol squat on decline angle and muscle activity of the lower limbs, and to rehabilitate the hamstring muscle. The conducted research allowed to show a significant increase in hamstring muscle activity, a decline in knee joint angle, also demonstrating slight increases in the quality of pistol squat and significant changes in ordinal scale values from the pre- to post-test. Significant changes in scores from ‘very poor’ to ‘poor’, ‘poor’ to ‘normal’, and ‘normal’ to ‘optimal’ were noted for the ordinal scores.

The pistol squat also belongs to closed-chain activities. It is very difficult to perform, but in this study, all the...
participants achieved the optimal decline angle in order to improve hamstring muscle flexibility and prevent hamstring amnesia.

Benefits of performing the pistol squat are isolation of each leg for balancing to prevent strength deficits with more muscle recruitment of the lower limb. This allows to improve the posterior chain strength and increase general flexibility as well as mobility along the posterior chain with increases in ankle joint mobility and flexibility. Furthermore, strengthening of stabilising muscles in the leg is improved, as well as proprioception though the leg and core.

The inhibitory effect of one group of muscles on the others around the hip and knee joint during the pistol squatting activity increases the test value variable. The possible inhibitory effect is reciprocal inhibition which comes into action when 2 opposing groups of muscles have to work in synchrony with each other to produce a smooth coordinate movement.

The quadriceps muscle is in repeated contraction, synchronised with the hamstring muscle when the knee flexes and extends during squatting activity.

Squats require movement of the hips, knees and ankles, forming a compound exercise that requires involvement of numerous muscles. Although the hamstrings are commonly associated with knee flexion, they assist hip extension during the squat. Hamstrings are responsible for handling a large percentage of the load on the hips. Their weakness can limit squat performance and put the subject at risk of injury in the knee joints.

Hamstrings are active throughout a squat, controlling speed on the way down and helping to come back up.

*Hamstring involvement*

The hamstrings comprise 3 muscles, including the *biceps femoris, semitendinosus* and *semimembranosus*, which run down the back of the upper thighs. The hamstrings originate at the back of the pelvis and travel down the leg, where they then insert at the top of the tibia and fibula, located in the lower leg. Because the hamstrings cross both the hips and knees, they are able to contribute to movements in both joints. As one lowers into the squat, the hamstrings assist the gluteal muscles by controlling flexion at the hips. Rising up out of the squat, the hamstrings contract and work against resistance to extend the hips.

**Conclusions**

In this study, the squatting activity had significant effects on flexibility of the hamstrings and increased muscle activity, achieving the optimal knee joint decline angle in the healthy population.

In this trial, pistol squats were mostly performed using the dominant leg, but in the pre-test, the non-dominant leg also demonstrated muscle activity.

**Recommendations**

- In a healthy population, where tightness is a common factor because of a sedentary lifestyle, the pistol squat activity can be recommended to maintain flexibility.
- Future research can be carried out to compare the kinematics and lower limb muscle activity of both the dominant and non-dominant sides.
- The electromyography of all individual thigh and leg muscles can be concentrated.
- The study was focussed only on the decline angle of the knee joint, which does not cover the remaining angles such as shank and quadriceps angle.
- Awareness can be created to prevent musculoskeletal disorders.

**Limitations**

- The study is limited because of the healthy female population.
- The study can also be carried out among different sports populations.
- The surface electromyography method was limited to the superficial muscles.
- The study is limited because of motion analysis.
- The study is limited to concentrate other components of the pistol squat such as non-stance limb electromyography and hamstring muscle activity.
- The study is not focused on the horizontal plane pistol squat.

**Institutional Review Board Statement**

The research was approved by the Institutional Ethics Committee Discussed at SRM College of Physiotherapy, SRMIST (No. 1909/2020).
References:


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## APPENDIX I
### MASTER CHART

### PRE-TEST

<table>
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<th>S. No.</th>
<th>Hamstring muscle activity (surface EMG) MUAP-AREA</th>
<th>Decline angle or knee rom</th>
<th>Ordinal scale</th>
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<td>1</td>
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<td>64</td>
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## POST-TEST:

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<td>16</td>
<td>942.89uv.ms</td>
<td>80</td>
<td>3</td>
</tr>
<tr>
<td>17</td>
<td>1159.68uv.ms</td>
<td>85</td>
<td>4</td>
</tr>
<tr>
<td>18</td>
<td>1292.43uv.ms</td>
<td>86</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>869.22uv.ms</td>
<td>71</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>1349.16uv.ms</td>
<td>90</td>
<td>4</td>
</tr>
</tbody>
</table>

### Ordinal scale scoring:

<table>
<thead>
<tr>
<th>Degrees</th>
<th>Ordinal score</th>
</tr>
</thead>
<tbody>
<tr>
<td>55-60</td>
<td>1 (very poor)</td>
</tr>
<tr>
<td>65-70</td>
<td>2 (poor)</td>
</tr>
<tr>
<td>75-80</td>
<td>3 (normal)</td>
</tr>
<tr>
<td>85-90</td>
<td>4 (optimal)</td>
</tr>
<tr>
<td>95-100</td>
<td>5 (good)</td>
</tr>
</tbody>
</table>