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The Effects of Squat Exercises on the Space between the Knees of Persons with Genu-varum

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Abstract

Background/Objectives: The purpose of this study was to find out the effect of squat exercise on the space between the knees and a distance of global postural system of deformity. **Methods/Statistical Analysis:** Twenty-two volunteers took part in this study and we divided into two groups(experimental group 10, control group 12). Experimental group performed toe in squat exercise and control group performed general squat exercise. All volunteers received a total of 18 exercise session over a 6-week period (three times per week). Repeated ANOVA was used to examine the effects of the intervention on each outcome measure. **Findings:** The space between the knees and a distance of GPS wasgreatly reduced in the experimental group. Therefore, we have confirmed through experiments reducing a space between the knees toe-in squat, whereby we would also be helpful to ensure the treatment of genu-varum. **Application/Improvements:** Furthermore, based on the results of this study, the supplementation and addition of diverse exercises to correct genu-varum are considered necessary.

Keywords: Global Postural System, Patella, Squat Exercise, Toe-in, Vastus Medialis

1. Introduction

The knee joints allow static and dynamic stability on one's weight bearing stance in everyday life. Knee joint stability is important in the closed kinetic chain since most knee joint injuries affect the weight-bearing stance[1].

Genu-varum postures are caused by the composite actions of femoral head intorsion, the supination of both feet, and excessive knee extension, all of which affect the separation of the knees[2]. In practice, moderate and less severe genu-varum (5 cm) can be corrected by stretching. However, severe genu-varum requires surgery for correction[3]. The review of the relevant literature revealed that genu-varum was corrected by diverse exercise methods. Several direct and indirect studies were conducted on rehabilitation programs. One study in the field of sports medicine indicated that stretching exercises were performed to prevent injuries, reduce pain, improve muscle tone after physical activity, and increase the range of motion of joints. In the field of rehabilitation medicine, stretching exercises were applied to increase the functional recovery and range of motion of joints and after injuries or fixation[4]. In a study by reference[5], persons with genu-varum performed corrective exercises combined with band exercises, stretching, or sling exercises. The findings showed that changes in the space between the knees did not show any significant differences among the groups before exercise, at six weeks of exercises, or at 12 weeks of exercises. However, the space between the knees showed significant decreases from before the exercises, after six weeks of exercises, and after 12 weeks of exercises, which indicated that the space between the knees was gradually decreasing. Exercise methods used to correct genu-varum include basic stretching of the adductor

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muscles, exercises that strengthen the lateral rotator muscles, exercises to stabilize the patellae, and sling exercises for structural changes in the adducted tibiae. When these exercises were performed three times per week for 12 weeks, all hip joint angles, Q angles, and the space between the knees showed significantly positive changes.

Although squat exercises are used to enhance performance in many sports events, they are also utilized in rehabilitation programs because they are effective in the process of rehabilitation after knee surgeries, such as anterior cruciate ligament restoration surgery[6]. Squat exercises are a good example of closed chain exercises that target knee joint flexion, hip joint flexion, and ankle joint flexion. They have been shown to minimize the stress on the anterior cruciate ligament by reducing the shear force on the knee and femoral joints through compressive force and co-contraction[7].

Squat exercises are functional because strengthening the quadriceps through weight bearing requires the movement of more joints than non-weight bearing exercises do. Furthermore, squat exercises have been shown to promote functional patterns of muscle mobilization and stimulate the proprioceptive sense[8]. [9] reported that the proprioceptive training program is more effective in the rehabilitation of acute ACL injury in athletes than non-operative standard rehabilitation program alone.In addition, closed chain exercises have been shown to be capable of providing functional muscle mobilization patterns by multi-joint movements[10].

Therefore, the purpose of the present study is to examine the effects of squat exercises performed by subjects with genu-varum on the space between their knees and on the correction of lower limb malalignment. The study aims to provide scientific and objective verification of the effects of exercise therapies on genu-varum.

2. Materials and Methods

2.1 Participants

In the present study, 22 male and female students at K University in Busan performed exercises three times per week for six weeks from March 23 to May 15, 2015. The study subjects were selected from among candidates that (i) agreed to participate in the experiment with sufficient understanding of the purpose and method of the study, (ii) had no congenital or acquired musculoskeletal disease, and (iii) were suspected of genu-varum symptoms based on the results of posture measurement taken by Global Postural System (GPS).

2.2 Study Method

A toe-in squat exercise group (experimental group) of 10 subjects and a general squat exercise group (control group) of 12 subjects were randomly selected. In the present study, each exercise program consisted of three sets of motions performed 20 times per session, three times per week for six weeks. In the case of the toe-in squat exercise, the hip joint adduction angle in the starting posture was measured at 20˚. Thereafter, the posture was taken by placing the participants' feet in a triangle shape with the short leg facing front, and then the squat motion was performed (Figure 1). The general squat was performed in a posture with the feet apart at shoulder width and the knees in 45˚ flexion (Figure 2).

2.3 Measurement tools and method

2.3.1 Whole Body Posture Measurement System

In the present study, a whole body posture measurement system (GPS 400, Red Balance, Italy) was used to judge whether the subjects had genu-varum. GPS 400 can be used to identify asymmetry in the body by using the centerline, vertical lines and horizontal lines on the front, rear, left-, and right-side shapes of the body by measuring postural changes through photo shooting[11].

2.3.2 Measurement of the Space between the Knees

The space between the knees was measured using measurement plates. The subject was instructed to stand on

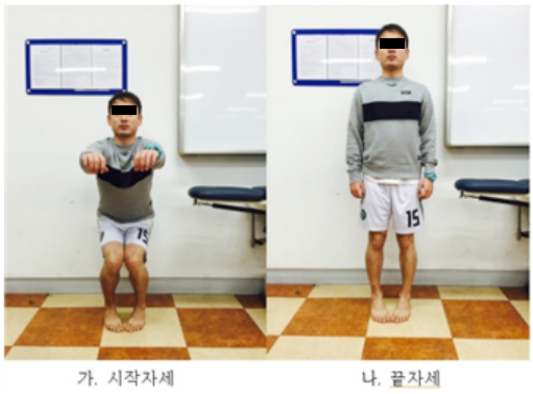

Figure 1. Toe-in squat exercise.

Figure 2. General squat exercise.

the measurement plate looking forward and placing the feet so that the big toes were on the center of the front edge of the square. The space between the knees was measured by centering on the patellae. The width of one cell on the measurement plate was 0.5 cm.

2.4 Statistical Analysis

The data collected in the study were analyzed using the SPSS statistical package (version 22.0, SPSS, Chicago, IL, USA). The participants with genu-varum were divided into two groups: 1) the control group performed general squat exercises; 2) the experimental group performed toe-in exercises. Repeated measures ANOVAs were conducted to compare the effects of the exercises over time. The statistical significance level was set at $\alpha = .05$.

3. Results and Discussion

3.1 Results

3.1.1 General Characteristics of the Study Subjects

The subjects were divided into an experimental group (toe-in squat exercise group) of 10 subjects and a control group (general squat exercise group) of 12 subjects. The mean ages, mean heights, mean weights, mean BMIs, and mean spaces between the knees of the experimental group and the control group are shown in Table 1. In addition, the kurtosis and skewness values were analyzed to test normality. The results showed normal distributions in both groups.

3.1.2 Changes in the Space between the Knees over the Experimental Period

The changes detected in the spaces between the knees of the experimental group and the control group following the squat exercises for six weeks are shown in Table 2. The

Table 1. General characteristics of subjects

Variable	Exp G (n=10)	Con G (n=12)
Year (y)	021.40y)=12	22.83±5.44
Height (cm)	167.50 (cm)	167.61±9.62
Body Weight (kg)	056.52eight	60.562eight
BMI(kg/m.0	020.18/m.0t	21.428/m.0
Space between the knees (cm)	007.85betwe	6.1385betw

Exp G: Experimental group(toe-in squat exercise group)
Con G: Control group(general squat exercise group)
BMI: Body Mass Index

results of Mauchly'sphericity test confirmed the validity. The intragroup effects over the experimental period were tested. The results showed that the spaces between the knees were changed statistically significantly over the experimental period ($p < .05$), and there was no interaction between the experimental period and the groups ($p < .05$). The effects of the exercises were compared between the groups. The results showed statistically significant differences ($p < .05$) between the groups. The results of the tests of the intragroup effects over time showed statistically significant differences between the beginning of the experiment and at six weeks, between two weeks and six weeks after the beginning of the experiment, and between four weeks and six weeks after the beginning of the experiment ($p <.05$) (Table 2).

3.1.3 Changes in GPS Values over the Experimental Period

The rates of changes in GPS values over the six weeks of squat exercises performed by the experimental group and the control group are shown in Table 3. The results of Mauchly'sphericity test confirmed that sphericity was valid, which indicated that the changes in GPS values over the training period were statistically significant ($p < .05$), and there was no interaction between the experimental period and the groups ($p < .05$). The effects of the exercises were compared between the groups. The result showed no statistically significant differences ($p > 0.5$). The results of the tests of the GPS values in each group over time showed statistically significant differences between the beginning of the experiment and at six weeks, between two weeks and six weeks after the beginning of the experiment, and between four weeks and six weeks after the beginning of the experiment ($p < .05$) (Table 3).

Table 2. Changes in the space between the knees over the experimental period

	0 week	2 week	4 week	6 week	F	p
Exp G	7.85Ges i	7.77Ges i	7.61Ges i	7.01Ges i	37.95	.00*
Con G	6.13Ges i	6.10Ges i	5.94Ges i	5.60Ges i		

*significant ($p<0.05$) difference between Exp G and Con G

Table 3. Changes in GPS values over the experimental period

	0 week	2 week	4 week	6 week	F	p
Exp G	16.57ks i	16.49ks i	16.36ks i	16.30ks i	64.01	.00*
Con G	15.77ks i	15.69ks i	15.59ks i	15.56ks i		

*significant ($p<0.05$) difference between Exp G and Con G

3.2 Discussions

The present study examined the effects of squat exercises on the space between the knees of participants with genu-varum. The subjects in performed general squat exercises or toe-in squat exercises for six weeks, and the spaces between the knees were measured using measuring plates and GPS.

Genu-varum postures are caused by the composite actions of femoral head intorsion, the inversion of both feet, and excessive knee extension. When the femur is internally rotated, the axis for flexion and extension is placed obliquely to the frontal plane, which leads to knee separation and severe tilting of the tibiae. Hyperextension occurs toward the rear of this axis, which leads to knee separation and severe tilting of the tibiae. Legs with genu-varum undermine the function of the knee joints according to shape. Because the vastus medialis is the weakest physiologically, muscular atrophy shows first. Moreover, when it is damaged, the vastus medialis recovers the slowest. Damage to the vastus medialis leads to imbalance in the quadriceps femoris muscle, which causes mechanical changes around the knee joint, resulting in patella subluxation[12]. The spaces between the knees identified in the present study were at least 7 cm on average, which previous studies have reported as capable of causing many problems.

In the present study, the toe-in squat exercise was designed by revising and supplementing the stretching and exercise programs presented by [13]. This exercise was implemented because it was judged more effective than general squat exercises in reducing the space between the knees under genu-varum. According to the results, the toe-in squat exercise was effective in reducing the space between the knees. In a previous study conducted by [13], the space between the knees significantly changed through the application of genu-varum correction exercise programs.[5] reported that when adult genu-varum patients (space between the knees at least 5 cm) performed band exercises, stretching, and sling exercises three times per week for 12 weeks—that is, 36 times—the spaces between the knees decreased. In addition,[14] reported that when a genu-varum correction exercise program using stretching and elastic bands was implemented for six weeks, the spaces between the knees significantly decreased.

In previous studies[11,15,16], GPS was used to measure genu-varum, and the πViewSTAR program was used to measure the angle. Similarly, the present study showed changes in GPS in the space between the knees in the experimental group and the control group. The results showed significant differences in the decreases in the space between the knees of the participants over the study period.

The present study has the following limitations. The results of the study cannot be generalized for the following reasons: the number of subjects was small; the spaces between the knees were determined by measuring the distance between the apparent center points of the patellae, which is less reliable than measurements taken through X-rays. In addition, because the experiment was conducted for the short period of six weeks, the long-term effects of the exercises could not be evaluated. Furthermore, the living environments of the participants in the experiment other than during their experiment were not taken into account. Further studies that consider these limitations should be conducted to determine the long-term persistence of the effects of the exercises used in this experiment.

4. Conclusion

Using the GPS, the present study examined changes in the space between the knees of participants in a control group, which performed general squat exercises, and an experimental group, which performed toe-in squat exercises. Based on the results, the following conclusions are stated:

1. The results of the analysis of changes in the spaces between the knees of the participants in the experimental group and the control group showed significant differences between the beginning of the experiment and at six weeks, between two weeks and six weeks after the beginning of the experiment, and between four weeks and six weeks after the beginning of the experiment. The spaces between the knees of the participants decreased more in the experimental group than in the control group.
2. The results of measurement of distances on GPS showed that the distances decreased over the study period in both the experimental group and the control group. The spaces between the knees decreased more in the experimental group than in the control group although the difference was not significant.

The results of this study indicate that the toe-in squat exercise can reduce the space between the knees. Therefore, it is recommended that the toe-in squat exercise should be applied in programs to correct genu-varum in adults. Future studies are required to overcome the limitations of the present study. Furthermore, based on the results of this study, the supplementation and addition of diverse exercises to correct genu-varum are considered necessary.

5. References

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