Original Article

The relationship between knee joint angle and knee flexor and extensor muscle strength

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Abstract. [Purpose] The aim of this study was to determine a relationship between joint angle and muscular strength. In particular, this research investigated the differences in maximum muscular strength and average muscular strength at the knee-joint posture. [Subjects and Methods] The study subjects comprised eight female students in their 20s attending S University in Busan. None of the subjects had functional disabilities or had experienced damage to the lower extremities in terms of measurement of muscular strength. A BIODEX system III model (Biodex medical system, USA) was used to measure joint angles and muscular strength. The axis of the dynamometer was consistent with the axis of motion, and measurements were made at 25° and 67° to examine differences in maximum muscular strength according to joint angle. [Results] The maximum muscular strength both knee-joint extension value, at 67° and flexion value, at 25° the value was larger. The average muscular strength both knee-joint extension value, at 67° and flexion value, at 25° the value was larger. [Conclusion] The results of this study reveal that muscular strength does not reach maximum at particular range angles, such as the knee-joint resting posture angle or the knee-joint middle range angle. Rather, a stretched muscle is stronger than a contracted muscle. Therefore, it is considered that it will be necessary to study the effects of the joint change ratio on muscular strength on the basis of the maximum stretched muscle.

Key words: Knee joint angle, Knee flexor, Knee extensor

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INTRODUCTION

The knee is one of the weight-bearing joints in the human skeleton. The joint itself is slightly unstable, partly because it assumes an intermediate position in the muscles and ligaments and is subject to external forces. Normal knee joint alignment is enabled by balance between the vastus medialis and vastus lateralis¹⁾. Movement of the joint occurs through the contraction of muscles; the contractile force is closely related to the length of the muscle²⁾. In particular, because of the structural characteristics of the musculoskeletal system, activity levels during human muscle motion are conditioned to generate a significant difference depending on the joint angle³⁾. The magnitude of the change or the length of the muscles at the joint location have a significant effect on the maximum power generated by the muscle during the isometric contraction of the element that acts as the length, and the angle of the joint determines the maximum strength of the muscle⁴⁾. Various types of resistance training have been applied, not only for rehabilitation of patients but also for fitness management in healthy people, and these training programs are already known to have a positive effect on the improvement of muscle strength and endurance⁵⁾. Although resistance training is reported to be positively effective for the improvement of muscular functions, various programs that have not been scientifically verified are widely used⁶⁾. The American College of Sports Medicine (ACSM) points out that scientifically verified resistance training programs are needed to increase the effects of resistance training⁷⁾.

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Generally, resistance training is accompanied by a change in muscle length and thus in order to increase the training effects, it is important to determine an optimal muscular length and proper postures, taking into account the muscular length-tension relationship⁸⁾. Right from the planning stages of training therapy, it is also necessary to consider training postures and joint angles depending on training purposes⁹⁾. It is generally thought that muscular length changes depend on the joint angles that trigger changes in muscular strength. Therefore, it is reported that for each body joint, there is an optimal joint angle with dynamic advantage¹⁰⁾. At the optimal angle, muscles have the correct length to exert the maximum strength¹¹⁾. Unfortunately, few studies have been conducted to determine the joint angles that exert this maximum muscular strength. Therefore, the present study attempts to investigate the relationship between joint angle and muscular strength in the knee joint. The aim of this study is to unreasonable posture can minimize the damage caused by comfortably carry out motion when performing the resistance for the purpose of promoting health or rehabilitation.

SUBJECTS AND METHODS

The subjects of this study were female students from S University in Busan City. These subjects fully understood the purpose and methods of the study, which complied with the ethical standards of the Declaration of Helsinki. Written informed consent was obtained from each participant. None of the subjects had any functional disabilities or had experienced damage to the lower extremities in terms of measurement of muscular strength. Regarding their general characteristics, on average, they were 21.8 years of age, and were 161.7 cm in height and weighed 55.4 kg. To determine the relationship between joint angle and muscular strength, knee joints were chosen for ease of measurement. The BIODEX system III model (Biodex medical system, USA) was used to measure joint angles and muscular strength. Each participant was asked to sit in the Biodex system chair and affix their shoulders, breast, and pelvis to the chair with the belt to prevent strength being exerted from anybody region other than the lower extremities; the femoral region was fixed with the femoral fixing belt. The shin pad was placed about 2 cm above the calcaneus of the ankle joint, which is a point of strength, and was fixed with a Velcro strap. The axis of the dynamometer was consistent with the axis of motion, and measurements were made at 25° and 67°; 25° is the angle of the general resting position of the knee joint, and 67° is the angle in the middle of the knee joint's total range of motion. The isometric muscular strength at extension and flexion was measured at each knee angle. First, the isometric muscular strength at extension was measured, and after 10 seconds of rest, the isometric muscular strength at flexion was measured. These measurements were repeated three times. When measurement at one angle was completed, the study subject had 3 minutes of rest. For the analysis, the maximum muscular strength value and average muscular strength value were used. For statistical analysis of the measured values, the SPSSWIN (ver. 23.0) program was employed; the significance level was established at $\alpha=0.05$. To examine differences in maximum muscular strength depending on the joint angle, a paired comparison t-test was conducted.

RESULTS

The results of the analysis of maximum muscular strength depending on knee joint angles are presented in Table 1. The right knee-joint extension value at 25° was 55.7, and at 67°, it was 94.6; thus, the value was larger at 67° ($p<0.05$). The left knee-joint extension value at 25° was 66.0, and at 67°, it was 101.5; thus, the value was larger at 67° ($p<0.05$). The right knee-joint flexion value at 25° was 54.6, and at 67°, it was 41.5; thus, the value was larger at 25°, but there was no statistical difference. The left knee-joint flexion value at 25° was 56.3, and at 67°, it was 42.7; thus, the value was larger at 25° and there was a statistically significant difference ($p<0.05$).

The results of the analysis of the average muscular strength depending on knee joint angles are presented in Table 2. The right knee-joint extension value at 25° was 52.2, and at 67°, it was 88.8; thus, the value was larger at 67° ($p<0.05$). The left knee-joint extension value at 25° was 62.7, and at 67°, it was 94.9; thus, the value was larger at 67° ($p<0.05$). In the case of the right knee-joint flexion, the value at 25° was 52.3, and at 67°, it was 39.7; thus, the value at 25° was larger ($p<0.05$). In the case of the left knee-joint flexion value at 25°, the value was 54.0, and at 67°, it was 41.0; thus, the value at 25° was larger ($p<0.05$).

Table 1. The changes of maximum muscular strength depending on knee joint (Unit: °)

Movement	Side	25°	67°
Extension	Right*	55.7 ± 16.1	94.67 ± 24.5
	Left	66.0 ± 20.6	101.5 ± 25.47
Flexion	Right	54.6 ± 13.5	41.5 ± 10.7
	Left*	56.3 ± 10.6	42.7 ± 11.9
Mean ± SD, * $p<0.05$			

Table 2. The changes of average muscular strength depending on knee joint (Unit: °)

Movement	Side	25°	67°
Extension	Right*	52.2 ± 16.3	88.8 ± 24.3
	Left*	62.7 ± 19.6	94.9 ± 25.3
Flexion	Right*	52.3 ± 13.7	39.7 ± 11.5
	Left*	54.0 ± 8.8	41.0 ± 11.8
Mean ± SD, * $p<0.05$			

DISCUSSION

From a biomechanical perspective, changes in a joint angle occur due to the contraction of the surrounding joint muscles, changes in the joint angle of a lever arm length, and the length of the muscle¹⁰⁾. Changes in muscle length according to the angle change in the joint causes a change in the force generated in the muscles. In addition, according to these joint angle changes, muscle activity changes³⁾. Therefore, in the respective joints of the body, there are joint angles that provide the optimum mechanical advantage¹⁰⁾. Knowledge about these angles is important because muscle function is determined by such mechanical properties as the strain related to the lever, and in order to plan effective programs for muscle strength enhancement, therapists must be aware of the relationship between the strength and the joint angle¹²⁾. A study by Na¹³⁾ showed that with an increase in the angle of the hip joint, measuring muscle activity at 90° to 160°, as compared to muscle activity when the angle change was from 90° to 130° degrees, results were consistent with the theory that the force increases as the muscle lengthens. These results are consistent with our results that showed greater muscle activity in the 67° knee angle than in the 25° angle, increasing slightly less than the length of the muscle at rest. Accordingly, the results of the present study did not reveal that muscular strength was the greatest at a particular range of angles, such as the knee-joint resting posture or the knee-joint middle range angle. Rather, it indicated that stretched muscle is stronger than contracted muscle. Therefore, it is necessary to study the effects of the joint change ratio on muscular strength on the basis of the maximum stretched muscle.

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