

The Change in Knee Angle during the Gait by Applying Elastic Tape to the Skin

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Abstract. [Purpose] The aim of this study was to verify how the application of elastic tape to the anterior surface of the thigh changes the knee angle pattern during gait. [Subjects] The subjects were 10 people who showed an abnormal knee angle change pattern during usual walking. They did not show the so-called double knee action. [Methods] Subjects were asked to walk as usual, and then to walk with elastic tape attached to the anterior surface of the thigh. The knee angle was measured during gait with an electronic goniometer. We graphed the temporal changes of the knee angle and compared them with the normal gait pattern. [Results] The knee angle gait pattern of six of the 10 subjects improved after application of the tape and became like a normal gait pattern. The changes in the knee angle resulted from a stimulus via the skin, rather than voluntary muscular adjustment, suggesting that the changes may have originated due to differences in reflexive tensile strength. [Conclusion] In normal speed gait, it is suggested that the knee angle was altered such that it exhibited a normal pattern by applying elastic tape to the anterior surface of the thigh. We suspect that application of the elastic tape may change the muscle tonus.

Key words: Gait, Knee angle, Kinesio tape

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INTRODUCTION

Because there are two knee flexions/extensions during one gait cycle, the motion of the knee during one gait cycle is known as the double knee action. In the normal gait, the time change curves of the knee angle have four extreme values: one for the angle of the heel contact phase, one for the angle of the mid-stance phase, one for the angle of the heel off phase, and one for the mid-swing phase. However, many people have a knee angle during gait that is different from the normal knee angle. That major reasons for this are thought to be slight muscle tonus changes. Therefore, we thought that it may be possible to change the muscle tonus by applying an elastic tape to the skin, which would change the knee angle during gait. As for the quadriceps femoris muscle, it is thought that the influence on the knee angle is bigger than that on other muscles. To ensure that the change induced by applying the elastic tape was not due to the placebo effect, we used Kinesio tape (Nitto Medical Corporation, Osaka) as the elastic tape, applied it to the superficial skin of the quadriceps femoris muscles, and then observed the knee angle changes during gait. We herein report the kinds of knee angle changes that occurred.

SUBJECTS AND METHODS

Subjects

Beforehand, we measured the change in joint angle of the knee during one gait cycle in 64 females. The walking pattern was classified based on the measurement results, and ten of the 64 females indicated that their gait patterns were not normal. In this study, the normal range of gait patterns was decided based on the knee angle in consultation of the study of Murray et al¹⁾. Observation of double knee action indicated a normal condition.

The subjects were healthy females with a mean age of 22.1 years (SD 1.3 years). The purpose and measurement methods were explained to the subjects. Subjects participating in competitive sports were excluded from the study. This study was approved by the Himeji Dokkyo University life ethics committee (permission number: 77). After an explanation of the purpose and methods of this study, written consent was obtained from all subjects.

Methods

We used an electronic goniometer (TM-5110, Nihon Kohden, Tokyo, Japan) to measure the joint angle. The two lever arms of the electronic goniometer were fixed with tape so that the shaft center was located in the lateral epicondyle of the right thigh, and the lever arms of the goniometer were fixed to the lateral surface of the thigh and the lateral surface of the leg. When subjects were wearing the goniometer, the gap between the lever arms was confirmed with knees of the subjects in a straight position. Also, in order to ensure that the angle was accurate, we measured the position of 0

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and 60 degrees of flexion with a handheld goniometer, and the electronic goniometer reading were then compared to these readings. The output analog signals of the electronic goniometer were converted to digital data at 100 Hz by an EA8 data recorder (TEAC Corporation, Tokyo, Japan). At the same time, the waveform of the electronic goniometer was monitored by an RTA-1200 printer (Nihon Kohden). When the same waveform was observed five times or more, data for the next waveform was adopted as the data.

We instructed the subjects to walk in their usual manner. The walking path was a plane painted with elastic urethane resin, and the right knee angle was measured with the bare foot. We measured the angle during a free walk and adopted the waveform data for one gait cycle after a stable waveform had been observed for more than five gait cycles. The first time, we instructed the subjects to walk normally, and the second time, we instructed them to walk after application of the elastic tape. The tape was 37.5 mm wide and was made by Nitto Medical Products (Japan). It was attached to the surface of the rectus femoris, vastus lateralis and vastus medialis and was extended to 110% of the normal length.

The measured waveforms had four areas with extreme values. The first extreme value was the maximal knee extension angle during the heel contact phase, the second value was the maximal knee flexion angle in the mid-stance phase, the third value was the maximal extension angle in the last standing phase, and the last value was the maximal flexion angle in the swing phase. Each extreme value and the duration of one gait cycle were calculated. With the four extreme values used as specific criteria, the gait patterns were classified into five types and a compound type (Fig. 1). Type 1 was assumed to be a normal type that shows double knee action. In the type 1 pattern, the first and third extreme values were less than five degrees, the second extreme value was more than 10 degrees, and the entire curve was smooth. In cases where the first extreme value was more than five degrees, the pattern was defined as type 2. The pattern was defined as type 3 when the third extreme value was more than five degrees, and it was defined as type 4 when the second extreme value was less than 10 degrees. Type 5 was defined as the case when the abovementioned wave motion was found twice between the first extreme value and the second extreme value. The compound type was a pattern in which multiple types were found; for example, a mixture of type 2 and type 5 was indicated as type 2+5. To compare the results based on the presence of the tape, we used the Wilcoxon-Mann-Whitney test, and the level of significance was set at 5%. The statistical analyses were performed with the R2.13.0 software.

RESULTS

The following points were found following application of the extensibility tape. After application of extensibility tape, the average first extreme value of the knee angle was decreased, the average second extreme value was increased, the average third value was decreased, and the average fourth extreme value was decreased, but none of the angle changes was significant (Fig. 1). When we did not apply the extensibility tape, the gait cycle was 1.06 (\pm 0.05)

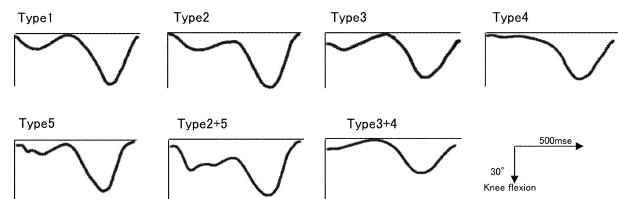


Fig. 1. Representative waveforms for the knee angle during gait for the different types.

Type 1 had extreme first and third values of less than five degrees, the second extreme value was greater than 10 degrees, and the whole curve was smooth. Type 2 indicates that the first extreme value was higher than five degrees. Type 3 is defined as a pattern in which the third extreme value was more than five degrees. Type 4 was defined as a pattern in which the second extreme value was less than 10 degrees. Type 5 was defined as the case when the abovementioned wave motion was found twice between the first extreme value and second extreme value. The compound type was a mixture of the above patterns, for example, a mixed type pattern of types 2 and 5 was indicated as type2+5.

sec, but when the extensibility tape was used, the gait cycle was 1.02 (\pm 0.06) sec.

After applying the extensibility tape, the knee angle change pattern became normal in five subjects (subjects one, three, four, seven, and eight). However, a change in type was not found in three cases (subjects two, six, and ten). Subject five had shown a type 5 pattern, but after applying the tape, the pattern changed to type 2. Subject nine had shown a type 4+5 pattern, but this changed to a type 5 pattern. With regard to the characteristics of the change, three subjects with a type 5 pattern showed normalization. Overall, the gait of five subjects changed to a normal type pattern, three subjects showed no change, one subject changed to another type, and one patient with a compound type changed to a single pattern type (Table 1).

DISCUSSION

It has been difficult to quantify the knee angle during gait by visual inspection. However, a mechanical goniometer²⁾ and image analysis³⁾ have now made it possible to quantify the knee angle. Recently, three axial angles have been reported to provide accurate results⁴⁾. It became easy to measure the angle with the development of new instruments and tools, and data analysis has been improved by new software programs. However, to track an image, it is necessary to apply marks on the skin surface. Therefore, an error can result from the movement of the marks, which is called a skin artifact. In addition, when performing image analysis using a video camera, an error can occur as a result of instrumental precision. Measurement of slight movements of the marks is difficult. In cases where a mechanical or electric goniometer is used, skin artifacts decrease, because the femoral region and lower leg are wrapped with a belt to fix the two arms of the goniometer. However, a belt is sometimes used to fix the patellar tendon when treating knee injuries, so the belt cannot be removed, and this

Table 1. The knee angle change pattern, gait cycle, and knee angle during gait

Tape application	1st angle(°)		2nd angle(°)		3rd angle(°)		4th angle(°)		Gait cycle(s)		Knee angle pattern	
	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
Sub.1	2.5	0.1	18.6	20.3	7.7	3.9	45.2	46.8	1.10	1.01	2	1
Sub.2	3.5	1.6	5.9	5.2	5.4	5.4	46.6	45.4	0.99	1.02	3+4+5	3+4+5
Sub.3	0.5	2.1	10.5	10.3	4.0	4.0	54.0	52.2	1.12	1.10	5	1
Sub.4	6.9	2.4	12.5	11.1	2.4	0.6	43.1	44.7	1.03	0.99	3+5	1
Sub.5	2.1	1.9	14.3	20.0	2.6	9.2	53.6	53.9	1.03	0.99	5	2
Sub.6	7.1	10.8	11.7	20.3	1.8	0.6	53.6	50.0	0.99	0.90	3	3
Sub.7	9.4	4.9	16.6	12.7	1.3	0.7	39.3	38.4	1.07	1.03	3	1
Sub.8	9.8	10.8	16.2	16.4	1.9	0.4	57.0	47.3	1.10	1.11	3+5	1
Sub.9	2.9	4.7	8.7	12.2	0.9	0.2	59.7	61.5	1.09	1.02	4+5	5
Sub.10	2.6	2.7	5.4	8.6	1.7	0.8	63.9	59.7	1.12	1.05	4+5	4+5
Mean	4.73	4.20	12.04	13.71	2.97	2.58	51.60	49.99	1.06	1.02		
SD	3.28	3.75	4.50	5.31	2.14	2.99	7.81	7.05	0.05	0.06		

Significant difference in gait cycle with tape compared without tape ($p < 0.05$).

may result in changes in the gait pattern. We developed a new method for assessing the gait pattern. We fixed the two arms of an electronic goniometer to the thigh and the side of the lower leg using tape. This method does not physically stimulate the knee flexors or extensors.

The subjects evaluated in the present study reported no subjective feeling of abnormality of the knee. However, they did not show a normal angle change pattern without the extensibility tape. In particular, seven patients showed flexure of the knee twice during the stance phase. We do not think that these motions during such short duration were controlled. Many subjects showed a tendency to have a shortened gait cycle, and the subject who switched over from type 5 pattern to a normal pattern did not show very much change. Based on these results, it was speculated that there was a muscle tone change and that the angle type of the knee changed.

In the type 5 pattern, a small change in knee angle during the stance phase is associated with femur motion relative to the tibia. This motion includes slip and rotation. In particular, within the range of 20 degrees to 40 degrees, the area of attachment between the femur facet and tibia facet is smallest, and the muscle tonus of the knee extensor and flexor are also the smallest. For the type 5 pattern, the muscle tension is insufficient between the heel contacts and mid-stance phases. Therefore, it is thought that a different pattern of knee angle changes appeared. This study clearly indicated that applying the elastic tape changed the knee movement. However, there have been many reports showing that improvements in exercise capacity, such as in muscular strength and vertical jump, are not observed when elastic tape is applied^{5, 6}). On the other hand, when flexure and extension of the knee were carried out at high speed, the hamstring muscle strength with application of elastic tape was higher than without the tape. There is also a report indicating that proprioception is improved by application of the elastic tape⁷). These reports indicate that application of elastic tape does not have an effect on conscious exercise performance but suggest that there is an effect on exercise

capacity during involuntary movement during exercise.

In this study, we showed that a change in gait pattern was induced by application of elastic tape to the legs of several subjects. The elastic tape does not appear to exert a significant physiological effect, but some subjects apparently changed their gait pattern involuntarily. It has been thought that the spinal reflex induced by skin irritation increases muscle strength and that this effect depends on the kinetic type and strength of the stimulation. In this experiment, application the elastic tape may have changed the muscle tonus.

However, the muscle contraction is small even during the mid-stance phase. The reason why the knee angle changed is currently unclear in terms of whether it was a conscious change or a spinal reflex caused by skin irritation. In addition, because the knee is affected by the hamstring muscles, the triceps muscle of the calf, and other side muscles, it is necessary to review the influences of these muscles and the influence of applying the pasting of the tape to the other side. Future studies, including neurological research, will be required in the future to elucidate the mechanism.

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