Original Paper

Influence of Difference in Knee Alignment on Site of Pain and Psychological State after Long-Distance Walking

Authors' Contribution:

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Manuscript Preparation
E – Funds Collection

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Abstracts. *Background and Study Aim: In this study, focusing on the individual difference in the characteristics of the knee joint, which plays an important role in weight bearing during walking, we examined the relationship between difference in knee alignment and pain in the legs during walking and effect of the pain on the psychological state of exercise performers. Material/Methods: A total of 40 subjects, including 25 healthy men and 15 women were recruited to this study. Knee alignment was classified according to the intercondylar and intermalleolar distances by increments of 2.0 cm. After walking (85km) on day 3 of the 5-day event, subjects were required to answer a questionnaire asking where in the leg they had pain. The psychological state of each subject was assessed by performing the Profile of Mood States (POMS) after they had rested after walking on each of days 1, 2 and 3 of the 5-day event. Results: The following sites exhibited significant differences in the number and incidence of injury between groups: the anterior side of lower leg ($p < 0.05$), posterior side of lower leg ($p < 0.01$), ankle joint ($p < 0.05$) and sole of foot ($p < 0.01$). In the genu valgum group, the score for factor V(:Vigor) decreased by 4.0 points between days 1 to 3: 18.1 ± 4.6 points on day 1 and 14.1 ± 7.6 points on day 3, with a significant difference between days 1 and 3. Conclusions: When performing an exercise that places load on the legs, such as walking, one should consider the risk of injury by measuring the individual's knee alignment before commencing the exercise.*

Keywords: *POMS, genu varum, genu valgum, injury, overuse*

BACKGROUND

Walking is generally recommended as a safe and effective aerobic exercise, and has been shown to be effective not only for burning fat but for prevention of such diseases as coronary heart disease, hypertension and diabetes [1,2,3]. Its effect on reduction of medical expenses is also attracting attention [4]. However, walking involves repeating the same movement for a sustained period of time and thus is associated with the risk of overuse of bones, muscles and tendons of the legs. Indeed, a close relationship between physical activity and occurrence of orthopedic diseases has been suggested [5]. Exercise performed to improve health may, in fact, cause orthopedic disease and in such cases continuation of the exercise is discouraged. A study to determine the maximum pressure exerted on the femorotibial joint during walking revealed that walking at a rate of 1.4 m/s exerts a force 4.6 times the body weight on the joint [6]. One of the conditions caused by this mechanism is knee osteoarthritis (OA). A previous study reported that OA can occur in 10% of individuals aged 55 years or older and may result in a reduction in the amount of exercise performed due to pain and functional disorder [7]. Pain in the knee joint can be caused by change in knee alignment and load exerted on the joint, such as body weight load [7]. A study has demonstrated that load exerted on the medial side of the knee joint due to joint malalignment [8] accelerates the progression of OA [9]. In addition to direct influence on the knee joint, knee malalignment also affects muscles and tendons; it alters the muscles activated during weight bearing [10] and causes some muscles to be locally stiffened following exercise [11]. Therefore, if a person with knee malalignment performs an exercise that involves repetition of a simple movement, such as walking, he or she may become unable to continue to perform the exercise due to localized pain. Salilis et al. [12] reported that more than 40% of the 500 subjects who had continuously performed exercise for 6 months or longer experienced "relapse" that prevented them from performing exercise for 3 months or longer, and that the most common reason for the relapse was injury. With regard to continuation of an exercise habit, the majority of people find it more difficult to maintain than to start an exercise habit; a study shows that nearly 50% of individuals who have started exercising drop out of the exercise program within 6 months [13].

Factors influencing continuation of an exercise habit include motivation, purpose of exercise, and psychological factors such as personality [14]. More positive factors, such as comfortableness during exercise, and fewer negative factors, such as uncomfortableness during exercise, should heighten motivation to continue exercising. Given a previous finding that transient exercise reduces anxiety [15], it is expected that exercise also has a positive psychological effect. However, no study has yet investigated the effect of long-term, continuous performance of light exercise, such as walking, on the psychological state of exercise performers, or common sites of pain associated with such exercise and whether or not the pain affects the psychological state of exercise performers.

In this study, focusing on the individual difference in the characteristics of the knee joint, which plays an important role in weight bearing during walking, we examined the relationship between difference in knee alignment and pain in the legs during walking and effect of the pain on the psychological state of exercise performers. On the basis of the results, we aimed to propose an effective and safe method of walking by measuring knee alignment prior to exercise in order that injury can be prevented.

METHODS

1.1 Subjects

A total of 40 subjects, including 25 healthy men (age: 21.2 ± 1.6 years, height: 170.4 ± 5.5 cm, weight: 67.3 ± 11.8 kg) and 15 women (age: 21.1 ± 0.7 years, height: 156.7 ± 5.3 cm, weight: 54.2 ± 7.8 kg) who had no previous medical history involving the legs and who participated in the walking event (5 days/4 nights: total walking distance is 140km), were recruited to this study. Knee alignment was classified according to the intercondylar and intermalleolar distances by increments of 2.0 cm (Fig. 1). Subjects with an intercondylar distance of <2.0 cm with an intermalleolar distance of <2.0 cm were considered to have normal knee, those with an intercondylar distance of ≥2.0 cm considered to have genu varum, and those with an intermalleolar distance of ≥2.0 cm considered to have genu valgum. The results of such classification are shown for all subjects in Table 1. Subjects with genu varum accounted for 40% (16 subjects), those with normal knee accounted for 35% (14 subjects), and those with genu valgum accounted for 25% (10 subjects) of all subjects. The study protocol was approved by the Human Ethics Committee of Konan University. Prior to participation, the risks and benefits of the study were thoroughly explained to all subjects and written informed consent was subsequently obtained.

1.2 Investigation of post-walking pain

After walking (85km) on day 3 of the 5-day event, subjects were required to answer a questionnaire asking where in the leg they had pain. We decided to carry out the investigation after the walking on day 3 based on the finding that delayed-onset muscle soreness (DOMS) reaches its maximum intensity between 24 and 72 hours after exercise [16, 17, 18, 19]. To exclude pain caused by scratches and blisters as examples, a separate section was provided for subjects to describe the site of these injuries. In addition, to prevent statistical errors due to difference in the subjects' knowledge about technical terms, an illustration of the human body was provided for subjects to mark the site of pain, along with a list of the types of pain (e.g. muscular pain, indefinite complaint, sprain, strain, swelling, stiffness and others) for their selection. Injury-related pain, such as pain resulting from sprain, was excluded from the obtained data and only data concerning overuse-related pain were collected. The number of pain episodes in each group was then determined from the collected data, and the number of episodes per subject was calculated by dividing it by the number of subjects. We also examined the relationship between site of pain and knee alignment by determining whether the site of pain differs among subjects, using the Kruskal-Wallis test. Significant differences were further assessed using a multiple comparison test.

Table. 1: Distribution of knee alignment. Subjects with genu varum accounted for 40% (16 subjects), those with normal knee accounted for 35% (14 subjects), and those with genu valgum accounted for 25% (10 subjects) of all subjects.

Type of knee	Genu valgum				Normal knee			Genu valgum			
Part of measure	Intercalcaneal distance					Intercondylar distance of the knee					
Distance [cm]	≤8.0	≤8.0-6.0	≤4.0-6.0	≤2.0-4.0	<2.0	0	<2.0	≤2.0-4.0	≤4.0-6.0	≤6.0-8.0	≤8.0
Number of Subjects	0	1	6	9	3	8	3	5	1	1	3
	16				14			10			

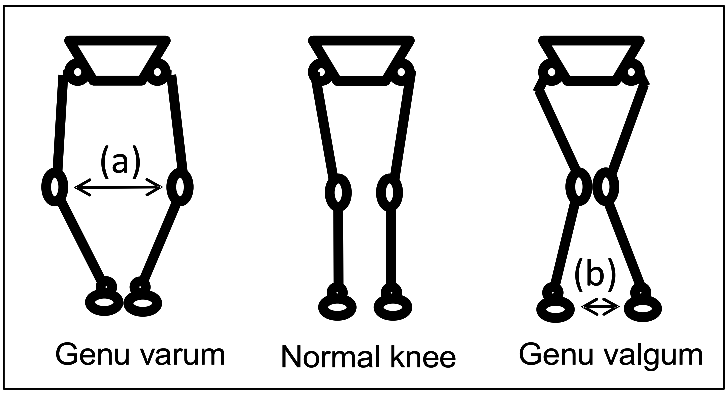


Fig. 1: Measurement of the knee alignment (a) Intercondylar distance of the knee, (b) Intercalcaneal distance

1.3 Assessment of psychological state

The psychological state of each subject was assessed by performing the Profile of Mood States (POMS) after they had rested after walking on each of days 1, 2 and 3 of the 5-day event. The psychological assessment was not performed 1 day before the final day of the event or at the end of the event in view of the possibility that feelings of accomplishment and fulfillment after completing long-distance walk may confound the assessment of relationship between actual pain and subjects' psychological state.

Scores for 6 scales of 1) Tension/Anxiety (T-A), 2) Depression/Dejection (D), 3) Anger/Hostility (A-H), 4) Vigor (V), 5) Fatigue (F), 6) Confusion (C) extracted by analyzing POMS factors were calculated for each subject based on the completed survey sheet. The mean score for each scale was calculated for each knee-alignment group and change over time in the mean score between days 1 and 3 was examined. For the purpose of assessing change in the psychological condition of subjects, we considered it more informative to examine change over time in the POMS scores within each group than to simply compare the scores between groups. We therefore assessed changes in the scores for each factor between days 1 and 3 using the one-way analysis of variance (ANOVA) to determine whether subjects' psychological conditions changed over time. Significant differences were further assessed using a multiple comparison test.

RESULTS

The number of episodes of pain per subject in each knee-alignment group was as follows: 2.4 episodes/subject in the genu valgum group, 2.2 episodes/subject in the genu varum group and 1.5 episodes/subject in the normal knee group, with no significant differences between groups. Table 2 summarizes sites and numbers of injury in each knee-alignment group, incidences of each injury per subject, and percentages of injury associated with each site relative to the total number of episodes in each group, which was calculated by dividing the number of injury episodes in each group by the total number of injury episodes in each site. The following sites exhibited significant differences in the number and incidence of injury between groups: the anterior side of lower leg ($p < 0.05$), posterior side of lower leg ($p < 0.01$), ankle joint ($p < 0.05$) and sole of foot ($p < 0.01$). The number and incidence of injuries in the anterior side of lower leg were significantly higher in the genu valgum group than in the genu varum group ($p < 0.05$) (Fig. 2-a); those in the posterior side of lower leg were significantly higher in the genu valgum group than in the other two groups ($p<0.01$) (Fig.2-b); those in the ankle joint were significantly higher in the genu varum group than in the other two groups($p < 0.05$) (Fig. 2-c); and those in the sole of foot were significantly higher in the normal knee and genu varum groups than in the genu valgum group ($p < 0.01$).

Changes in POMS scores over 3 days in each group are shown in Table 3 and Fig. 3. In the normal knee and genu varum groups, factor V exhibited the highest scores between days 1 and 3 while factor C exhibited the lowest scores, although the shapes of the graphs of both factors were similar. None of the factors exhibited significant changes in score throughout the 3 days in the normal knee and genu varum groups (Fig. 3a-b). Meanwhile, in the genu valgum group, the score for factor V decreased by 4.0 points between days 1 to 3: 18.1 ± 4.6 points on day 1 and 14.1 ± 7.6 points on day 3, with a significant difference between days 1 and 3 (Fig.3c).

Table. 2: Difference in knee alignment and sites of injuries

	Normal (N=14)			Genu varum (N=16)			Genu valgum (N=10)		
	No. of episodes	Incidence	%	No. of episodes	Incidence	%	No. of episodes	Incidence	%
Hip joint	2	0.1	20.0	6	0.4	60.0	2	0.2	20.0
Anterior side of thing	4	0.3	40.0	4	0.3	40.0	2	0.2	20.0
Posterior side of thing	2	0.1	33.3	2	0.1	33.3	2	0.2	33.3
Knee joint	3	0.2	42.9	3	0.2	42.9	1	0.1	14.3
*Anterior side of lower leg	1	0.1	20.0	0	0.0	0.0	4	0.4	80.0
**Posterior side lower leg	1	0.1	9.1	2	0.1	18.2	8	0.8	72.7
*Ankle joint	0	0.0	0.0	6	0.4	100.0	0	0.0	0.0
Toes	0	0.0	0.0	3	0.2	50.0	3	0.3	50.0
**Sole of foot	8	0.6	47.1	9	0.6	52.9	0	0.0	0.0
Heel	0	0.0	0.	0	0.0	0.0	2	0.2	100.0
Total	21	1.5	26.3	35	2.2	43.8	24	2.4	30

* p<0.05, ** p<0.01

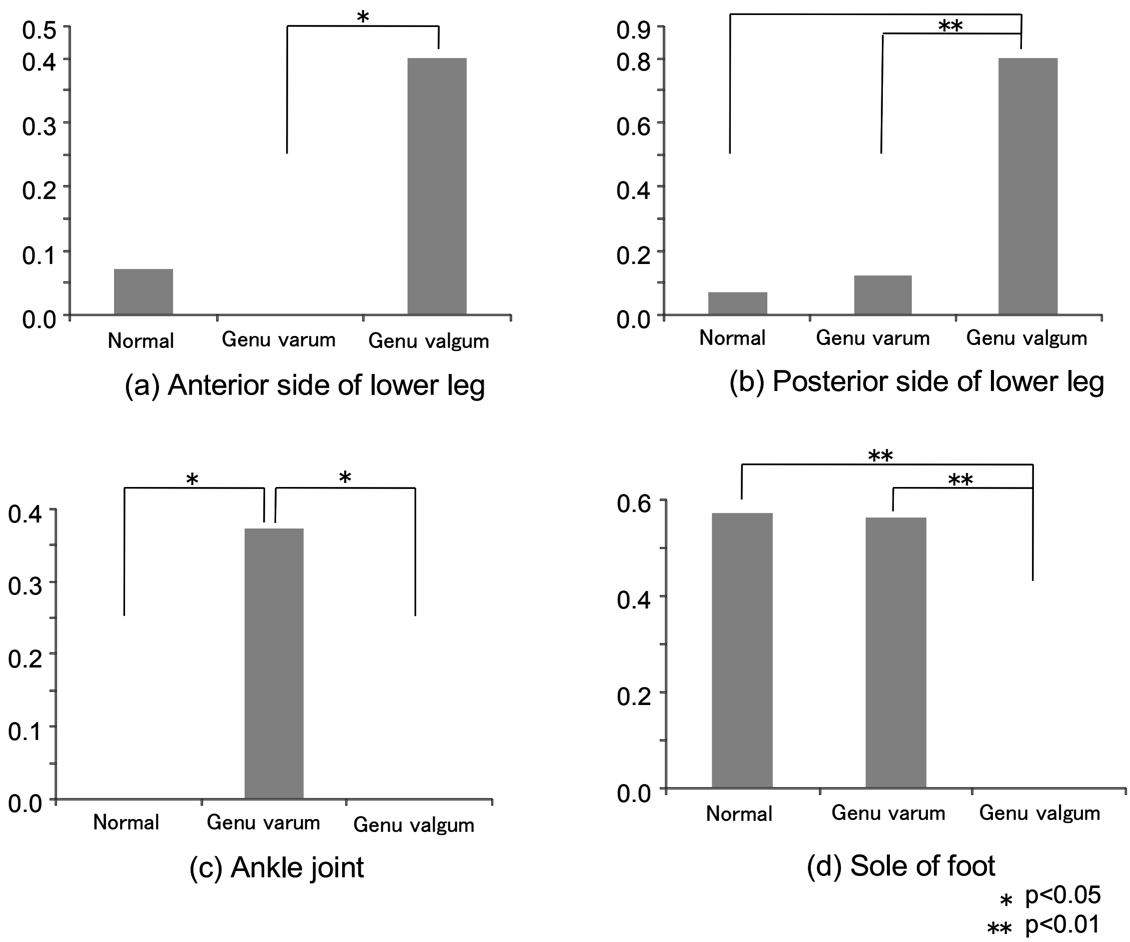
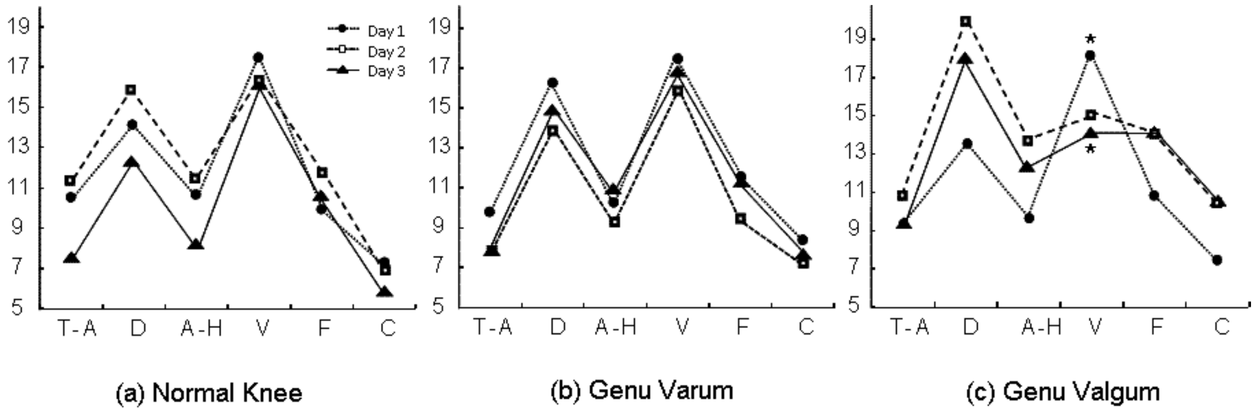


Fig. 2: Comparison of incidence of disorders in different sites

Table. 3: Changes in POMS values

	Normal			Genu varum			Genu valgum		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
T-A	10.6±6.3	11.4±8.2	7.6±8.6	9.8±8.8	7.9±6.2	7.9±6.0	9.3±6.2	10.8±6.6	9.3±6.0
D	14.2±12.8	15.9±11.9	12.3±10.6	16.3±14.9	13.9±13.2	14.9±14.1	13.5±10.5	19.9±14.9	18.0±15.7
A-H	10.7±9.5	11.5±8.9	8.2±8.6	10.3±10.4	9.3±9.3	10.9±9.5	9.6±5.3	13.7±10.1	12.3±12.1
V	17.5±7.6	16.4±9.2	16.2±8.3	17.5±7.9	15.9±8.3	16.9±8.3	18.1±4.6*	15.0±7.8	14.1±7.6*
F	10±7.1	11.8±8.0	10.6±7.2	11.6±5.6	9.5±7.1	11.3±6.7	10.8±5.1	14.0±7.0	14.1±6.3
C	7.3±4.6	6.9±6.0	5.9±5.7	8.4±5.9	7.3±4.5	7.7±5.7	7.4±4.1	10.4±4.9	10.5±5.6

* $p<0.05$



DISCUSSION

There should be less structure-related local stress exerted on the knee joint for healthy and free bipedal walking throughout life. In persons with normal knee alignment, walking exerts a force approximately 3.2 times the body weight on the knee, and 70% of the impact is absorbed in the medial knee [9]. The genu varum in the frontal plane exerts pressure on the medial knee [20] and therefore poses a high risk of knee damage [21,22].

Continuously performing physical activities such as walking in the presence of genu varum and disadvantageous knee structure increases the risk of degenerative disorders of the knee [23]. Moreover, continuously performing exercise in the presence of knee malalignment can cause an increase in Q-angle, thereby generating large force by the quadriceps femoris muscles that pull the patella outward, resulting in knee pain [24]. Therefore, difference in knee alignment probably alters the site of load application and patterns of muscle activity.

A study measuring the electromyogram activities of leg muscles during exercise in subjects with different knee alignment has shown different patterns of leg muscle activity among subjects[10], and another study measuring the hardness of leg muscles after exercise as a measure of fatigue in subjects with different knee alignment has also shown different patterns among subjects [11]. These findings indicate that different knee alignment can lead to load application at different sites even during transient exercise. It is thus likely that even during walking, different knee alignment leads to load application at different sites. In this study, the subjects in the normal knee and genu varum groups complained of pain in the sole of foot, and this is probably due to repeated application of stress and impact on the plantar aponeurosis during contact-toe off via the windlass mechanism. In persons with genu varum, the hardness of the muscles on the sole of foot significantly increases after leg presses [11]. In this case, excessive pronation of the ankle joint under load, which has been confirmed on video images [10], may be causing extension of the plantar aponeurosis. In contrast, in the genu valgum group, while none of the subjects complained of pain in the sole of foot after long-distance walking, the incidence of pain significantly differed between the anterior and posterior sides of lower leg. In persons with genu valgum, since the center of the knee joint is located medial to the Mikulicz line [25], valgus moment is easily generated in the knee joint during the stance phase. This results in inner rotation of the femur, pronation of the foot [26], and pulling of the muscles on the posterior side of the lower leg. This mechanism might have resulted in load on the triceps surae muscle and anterior tibial muscle, which are posture supporting muscles.

Assessment of psychological state during exercise has been performed [15,27], as well as the change in psychological state before and after transient exercise [15,28]. However, assessment results of psychological state after exercises accompanied by mental distress do not necessarily represent psychological state directly related to the exercise itself, since feelings of accomplishment and fulfillment after completing such exercises may confound assessment. Thus, assessment results obtained at the point during the exercise at which subjects' physiological fatigue is accumulated should represent subjects' mental state directly related to the exercise. This means that subjects' actual psychological state directly related to a given type of exercise can be assessed by recording their feeling in the middle of exercising, rather than recording changes in feeling before and after transient exercise or changes in psychological state before and after intensive or long-term exercise. If the exercise has a positive effect on the psychology of the exercise performer, the individual will be willing to continue the exercise. Conversely, if the exercise causes distress, the person will become reluctant to continue the exercise regularly.

Having less negative feelings and more positive feeling will facilitate continuation of exercise as a regular habit. In this study, we examined POMS factors until day 3, at which time muscular pain reaches maximum level [16,17,18,19], and the status of injuries during the period, finding no significant changes in the scores of any POMS factors between days 1 and 3 in the normal knee and genu varum groups. On the other hand, the genu valgum group exhibited a significant decrease in the activity factor V between days 1 and 3. With regard to site of injury, the genu valgum group reported pain on the anterior and posterior sides of the lower leg more frequently than the other two groups. None of the subjects in the genu valgum group complained of pain on the sole of foot, indicating that load exerted on the muscles in the lower leg, which supports posture, is more intense than the impact of landing exerted on the sole of foot. Thus, pain in the muscles of the lower leg may be responsible for the decrease in psychological activity.

CONCLUSION

Although a number of studies have been conducted on the effect and method of walking, none of these studies has given detailed consideration to individual physical characteristics, which may be one of the factors causing injuries and hindering the continuation of regular exercise. When performing an exercise that places load on the legs, such as walking, one should consider the risk of injury by measuring the individual's knee alignment before commencing the exercise.

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