Influence of Plantar Insensitive for Human Gait in Regular and Irregular Terrain

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Abstract— **The aim of this study was to investigate an influence of the plantar tactile sensibility during walking on regular and irregular terrain. Subjects were 8 healthy men (21.9 ±0.8 years old). In addition, we adopted an ice immersion to make plantar insensitive, and compared with normal (not iced) condition. In these experiments, the subjects soaked their soles to the ice water 30 minutes in the ice immersion. The measurements carried out 8 trials (one walking from the end to the end of walking road is defined one trial) on normal condition, and 8 trials after the ice immersion. The limitation such as the walking style and the walking speed was not especially instructed, and for all trials, the subjects were instructed to walk at their own pace, as if they were "walking to mail a letter." We conducted the experiments on even terrain and uneven terrain (32 trials in total per one subject). As a result, the results of the gait velocity (P<0.07), step length (P<0.96), and step width (P<0.5) on even terrain were not significant change after the ice immersion. By contrast, on uneven terrain, the gait velocity (P<0.01) and the step length (P<0.01) significantly decreased after the ice immersion. These results supported that the plantar insensitive significantly influence human gait on uneven terrain.**

Keywords— **Gait, Fall, Plantar sensation, Irregular terrain.**

I. Motivation

Walking is one of basic motion of human. However, walking has a lot of functions that have not understood yet. Falling accident can lead to serious damage such as bone fracture, hitting own head. Especially to elderly persons, the risk of fall accident increased more than young adults. In order to prevent fall accidents, it is necessary to understand the mechanisms of walking. Peripheral Neuropathy (PN) patients have less stability and more risk of fall during walking.[1] Various sensibilities (ex. vestibular, visual and somatosensory) are closely related with balance control.[2-5]However, sole is the only part to contact with the terrain, and the plantar sensation must have significant influence of human ambulation. Therefore, we hypothesized that the plantar insensitive leads to change walking motion. Then, gait on irregular terrain is more unstable than on regular terrain, and most of falling accidents occur during ambulation on irregular terrain.[2] However, in the researches that focused attention on plantar sensation, gait analyses statics on irregular terrain are hard to find[1 6 7]. The aim of this study was to investigate an influence of the plantar tactile sensibility during walking on irregular terrain. To verify the hypothesis, we conducted 3-dimensional measurement (the gait velocity, the step length and the step width were measured) by using a optical motion capture system. An artificial uneven terrain (as one of irregular terrain) was created. The ambulation data was compared on even terrain. To make plantar insensitive, ice immersion by using ice water was adopted.

II. Method

Method of measurements: Motions of subjects during walking were processed using the optical motion capture system (LIBRARY, HIMAWARI GE60/W). Subjects were 8 healthy young men (21.9 ±0.8 years old). They could walk with no difficulty and did not develop Peripheral Neuropathy (PN).

Artificial uneven terrain: We developed artificial uneven terrain for these measurements as one of irregular terrain. It used cloth carpet (8000[mm] in the total length ×910[mm] in width). This artificial terrain consisted of uneven area and flat area. In uneven area, the Bakelite (a kind of plastics) blocks (30[mm] in length ×50[mm] in width ×15[mm] in height) were arranged randomly on carpet backing and they make gait surface uneven. In the measurements, only steady-state gait were treated. Human needs about 3 steps on good condition (regular terrain) to obtain steady-state gait. Therefore, as flat area, 2000[mm] of flat terrain was placed short of irregular terrain for steady-state gait. Fig.1 shows the image of artificial terrain and Fig.2 is the photograph of artificial terrain.

Ice immersion: In this study, we need to make plantar insensitive to verify influence of the plantar tactile sensibility during walking. However, it is undesirable to block muscular activities by anesthesia. In past study, it had been found that cooling the soles can also make the plantar insensitive.[9] Based on this report, in our experiments, the ice immersion was adopted to subjects. Subjects soaked their sole to the ice water 30 minutes more continuously. In this time, socks and stockings were not worn to the sole. The soles were covered with thin polyethylene sheet in order to prevent modification of the skin by flood. Fig.3 shows image and photograph of the ice immersion.

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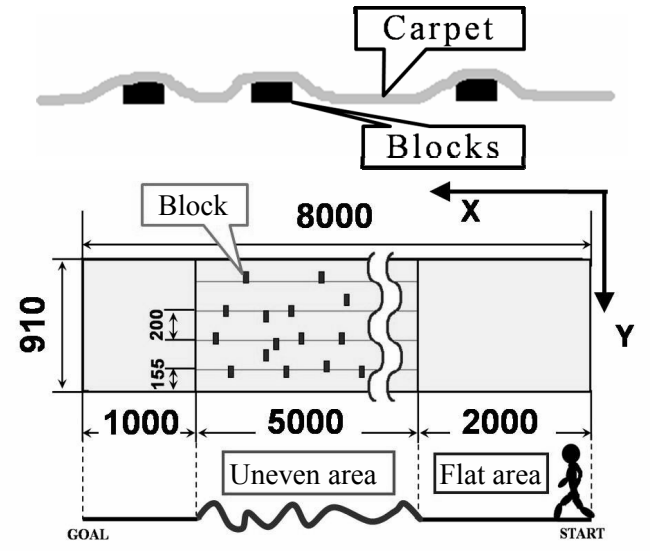

Fig. 1 Image of the artificial terrain

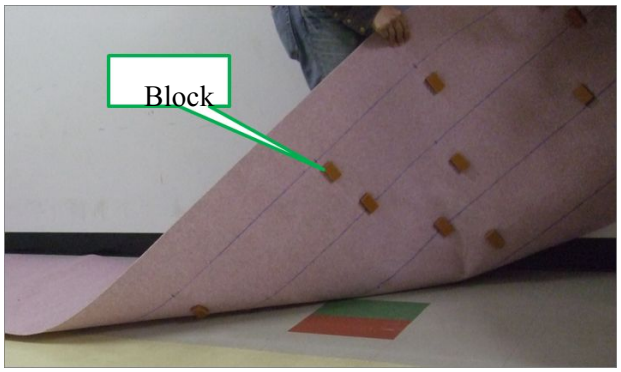

Fig. 2 Photograph of the artificial terrain

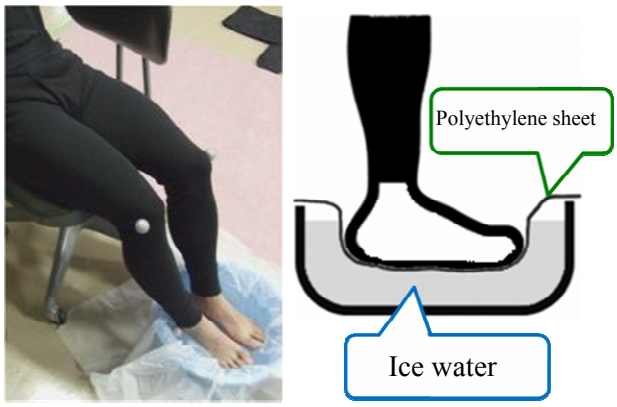

Fig. 3 Ice immersion

Experiments conditions: The measurements carried out 8 trials (one walking from the end to the end of walking road is defined one trial) on normal condition, and they were 8 trials after ice immersion. In order to compare with regular terrain, measurements on all flat carpet were also carried out in similar way. 32 trials in total were carried out for each subject. The limitation such as the walking style and the walking speed was not especially instructed. In all trials, subjects were instructed to walk at their own pace, as if they were "walking to mail a letter." Fig.4 shows photograph of the gait measurement.

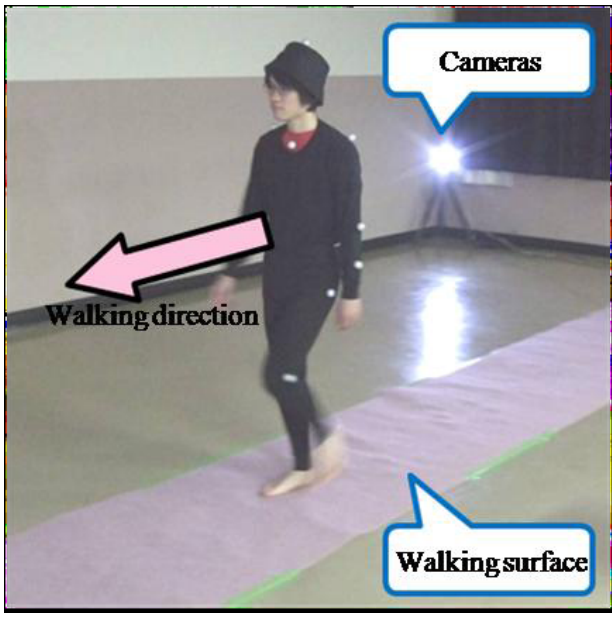

Fig. 4 The gait measurement

Statistical analysis: As Statistical analyses, t-test was used for all analyses. In this study, P-value < 0.01 was considered significant, P-value < 0.05 was considered to be a trend, and P-value > 0.05 was considered to be not significant.

III. Results

In this study, the gait velocity, the step length and the step width of the subjects were calculated from data of measurements. Table 1 shows the results of the measurement. The variability of the gait parameter means S.D. Fig.5 shows the results of measurement on even terrain, and Fig.6 shows the results of uneven (irregular) terrain. The markers in graphs mean the average of each gait parameters, and the error bars mean S.D. On even terrain, all of parameters did not significant change after the ice immersion. By contrast, on uneven terrain, the gait velocity (P<0.01) and the step

Table 1 The results of the measurements

The gait parameters	On even terrain		On uneven terrain	
	Normal	Iced	Normal	Iced
gait velocity [mm/s]	1324.78	1364.41	1283.74	1205.62*
gait velocity variability	136.03	145.97	116.27	113.14
step length [mm]	654.01	620.29	654.01	620.29*
step length variability	18.73	19.97	18.73	19.97
step width [mm]	174.43	174.43	176.76	176.56
step width variability	13.83	15.77	20.29	21.61

*P<0.01,compared on normal condition

length (P<0.01) significantly decreased after the ice immersion. In addition, the gait velocity and the step length on even terrain decreased more than that on uneven terrain.

IV. Discussion

In past studies, they reported that the decrease of gait velocity and step length is one of salient features of older person's gait.[] From this report and the result of this measurement, the gait of younger persons tend to resemble that of older persons by decreasing the sensitivity of plantar. Variability of gait parameters seemed to appear as instability of gait causes increased risk of fall,[9] however, variability of gait parameters was not found from the results. This

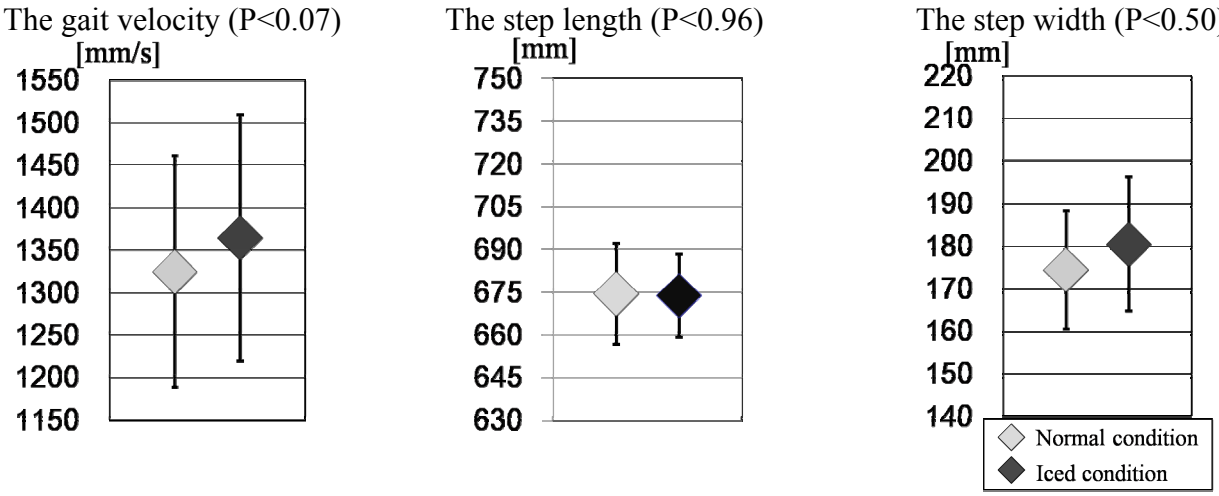

Fig. 5 The result of measurement on even terrain

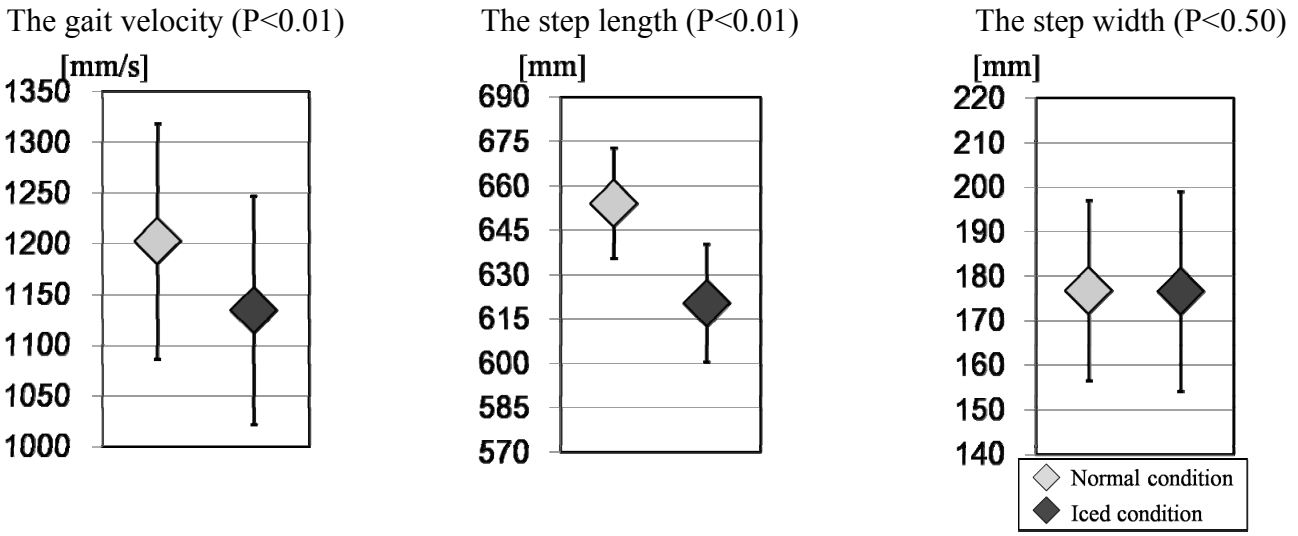

Fig. 6 The result of measurement on even terrain

supposed that the plantar insensitive did not cause increase of variability, however, decrease of gait parameters as a defensive behavior. Moreover, it caused that aging induces plantar insensitive. As cause of gait change of older persons, the various factors are cited such as loss of muscle strength, skeletal change and plantar insensitive and so on. However, it is unclear what causes fall of older persons during walking. The results of this study suggested that the plantar insensitive is considerable factor of gait change of older persons. At the same time, it supposed the hypothesis that the plantar insensitive leads to change walking and suggested that the plantar insensitive significantly performed during gait on irregular terrain. As related studies, the relation between plantar insensitivity and change of gait pattern with age are reported,[10] and aging causes increased risk of fall accidents.[2] Therefore, it is suggested that the plantar insensitive relates fall accidents of elderly persons and excitation of plantar sensation helps reduced risk for fall accidents.

V. Conclusion

The aim of this study was to investigate the influence of the plantar tactile sensibility during walking on regular and irregular terrain. To verify the hypothesis, we conducted gait analysis. As a result, the results of the gait velocity ($P<0.07$), step length ($P<0.96$), and step width ($P<0.50$) on even terrain were not significant change after the ice immersion. By contrast, on uneven terrain, the gait velocity ($P<0.01$) and the step length ($P<0.01$) significantly decreased after the ice immersion. These results supported that the plantar insensitive significantly influence human gait on uneven terrain. As future works, we will conducted more experiments with more variety of conditions. For example, there is no limitation of gait and this leads decrease of the gait velocity and the step length, but if the subjects are forced to walk maximum speed, variability of gait parameters cause falls may appears. In addition, the gait analysis with excitation of plantar sensation will be conducted for prevention of injurious falls. Muscle training imposes a heavy strain on older persons. We believe this study will help fruition of less onerous rehabilitation therapy for persons.

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References

1. James K. Richardson, Sibylle B. Thies, Trina K. DeMott, and James A. Ashton-Miller, “A Comparison of Gait Characteristics Between Older Women with and Without Peripheral Neuropathy in Standard and Challenging Environments”, *JAGS SEPTEMBER* VOL. 52, NO. 9, 2004.
2. William P. Berg, Helaine M. Alessio, Eugenia M. Mills and Chen Tong "Circumstances and consequences of falls in independent community-dwelling older adults ", Oxford Journals, Age and Ageing 26, pp.261-268, 1997.
3. R. Grasso, L. Bianchi, and F. Lacquaniti, "Motor Patterns for Human Gait: Backward Versus Forward Locomotion ", The Journal of Neurophysiology Vol. 80 No. 4, pp. 1868-1885, 1998.
4. Leah R. Bent, Bradford J. McFadyen, Veronique French Merkley, Paul M. Kennedy and J. Timothy Inglis, "Magnitude effects of galvanic vestibular stimulation on the trajectory of human gait", Neuroscience Letters Volume 279, Issue 3, 4, pp.157-160, 2000.
5. Stephen D. Perry, Luiz C. Santos, Aftab E. Patla, "Contribution of vision and cutaneous sensation to the control of centre of mass (COM) during gait termination", Brain Research 913, pp.27–34, 2001
6. Matthew A. Nurse, Benno M. Nigg, “The effect of changes in foot sensation on plantar pressure and muscle activity”, Clinical Biomechanics 16, pp.719-727 2006.
7. Eric Eils, Susann Behrens, Oliver Mersa, Lothar Thorwesten, Klaus Völker and Dieter Rosenbaum, “Reduced plantar sensation causes a cautious walking pattern” , Gait and Posture 20, pp.54–60 , 2004
8. Algafly AA, George KP, "The effect of cryotherapy on nerve conduction velocity, pain threshold and pain tolerance", British journal of sports medicine, 41(6), pp.365-9, 2007.
9. A. Gabell and U.S.L. Nayak, "The Effect of Age on Variability in Gait", Journal of Gerontology, Volume 39, 6, pp.662-666,1984.
10. Menz HB, Lord SR, Fitzpatrick RC, "Age-related differences in walking stability", Age Ageing, 32(2), pp.137-42, 2003.

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