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Original Article

Changes in gait stability induced by alteration of mandibular position

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The purpose of this study was to investigate the effect of different mandibular positions on the body equilibrium by measuring the gait rhythm. Twelve young healthy subjects volunteered to participate in this study. Subjects were instructed to walk for a 18m distance with the mandible guided at six different positions by occlusal splints. The gait was recorded at fast, ordinary and slow walking speeds under occluded condition. Gait cycle, coefficient of variation for gait cycle and gait velocity were calculated during the 10m-walk. One-way ANOVA with repeated measures demonstrated significant differences among the six mandibular positions for the gait cycle at all gait speeds, for the coefficient of variation at fast speed and ordinary speed and for the gait velocity at fast speed ($P<0.05$). Regarding these variables, multiple comparison tests were also performed between the mandibular position without instruction for occlusion and other five mandibular positions. Gait cycle, coefficient of variation and gait velocity changed significantly in 5mm opening position from the intercuspal position, and in 5 mm left and 5mm right position from the 3mm opening position at fast speed ($P<0.05$). The result of this study suggests that the change of mandibular position could affect the gait stability.

Key words: Mandibular positions, Occlusion, Body equilibrium, gait

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Introduction

The change of intercuspal position of the mandible is likely to occur when the occlusal collapse is neglected for a long term. It has been reported that the alteration of mandibular position influence variously on the body function as well as the oral function. Particularly, concerning the relation between mandibular position and body posture, several reports have suggested that the mandibular position influences body posture. The alteration of vertical dimension of occlusion causes changes of head and neck posture[1-3], leading to the disturbance in the body postural control[4,5]. In addition, as the body posture associates closely with the body equilibrium, the occlusion has also been regarded as one of factors that would affect the body equilibrium. Some studies have focused on the shifts of the center of body gravity for evaluating the body equilibrium function under the static condition. It was reported that the patients with temporomandibular disorders showed greater fluctuation in the center of body gravity compared with normal subjects[6]. It was also reported that even in normal subjects, the fluctuation in the center of body gravity increased by changing the mandibular position or providing the occlusal interference[7-9].

On the other hand, there are very few studies on the body equilibrium under dynamic condition. Maeda[10] investigated the body equilibrium of complete denture wearers using an equilibrium function test machine with the movable platform and showed that they demonstrated better body equilibrium function with dentures than without. Watanabe[11] examined walking patterns of complete denture wearers, indicating the possibility that wearing dentures would provide better body balance than not wearing. From these results, it is conjectured that the mandibular position would affect the body equilibrium not only in static condition but also in dynamic condition. However it has not been examined in detail that the mandibular position would affect spontaneous exercise. It is known that the body equilibrium is also influenced by moving speeds during spontaneously moving[12]. Thus it is necessary to consider moving speeds. Gait is one of the movements which represent spontaneous movement.

The purpose of this study is to investigate the influence of different mandibular position on the gait stability. The analysis of gait, which is one of the spontaneous movements, was employed to compare the gait rhythm among the different mandibular positions.

Materials and Methods

Twelve healthy men (24 to 28 years old, mean age 25.8 year), who had intact dentitions with stable intercuspal position, all teeth contacting opposing teeth at intercuspal position, and no signs or symptoms of temporomandibular and aural disorders, volunteered to participate in this study. All subjects were given information about the investigation to obtain their consent.

A telemetric measuring device (Gaitcorder MP-1200®, Anima, Tokyo) was used to record the times when the heel contacts the floor and the toe leaves during walking. This device consists of a pair of shoes with two strain gauges attached on the heel and the toe, transmitters and the processing unit. The electrical signals, which were detected by the strain gauges attached on the heel, were transmitted to the processing unit and the data were recorded (Fig. 1).

In advance of the measurements, the subjects kept sitting on a chair having the shoes on for 3 minutes, and then walked straight about 18 meters along a flat floor. To assure steady walking, the initial 4m-walk was excluded and the following 10m was used for analysis[13] (Fig. 2). The gait cycle was defined as a duration from a heel contact of the left or right foot to the next heel contact of the same foot. The means of gait cycle and coefficient of variation for the gait cycle were calculated in each trial. The gait velocity for each trial was calculated using the time required to walk for 10 m.

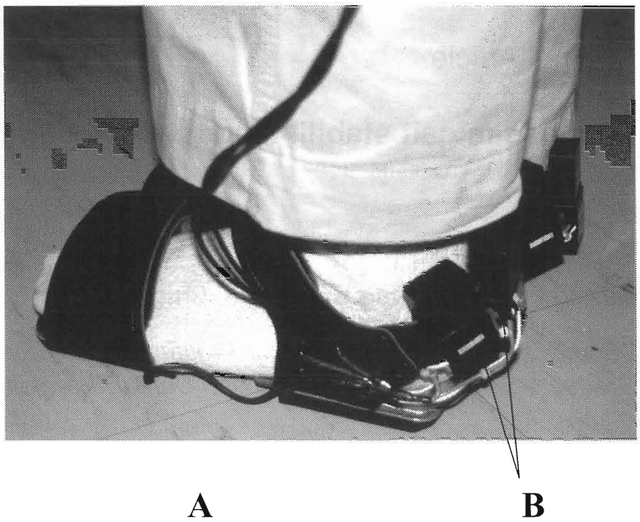

Fig. 1. Shoes of the measuring devices. A: strain gauges attached on the heels and toes of the shoes; B: transmitters attached to the shoes.

Table 1. Experimental conditions

Gait speed	Occluding condition
Fast	NI : no instruction of occlusion
Ordinary	IP : intercuspal position
Slow	U3: 3mm opening position from IP
	U5: 5mm opening position from IP
	UL: 5mm left position from U3
	UR: 5mm right position from U3

1. Experimental design

To investigate the influence of the mandibular positions on gait stability, the subjects were instructed to walk under the experimental conditions showed in Table 1. The mandibular positions were guided by the splints beforehand prepared. The splints were made for maxillary arch using light-cured acrylic resin to contact equally with all opposing teeth at each mandibular position. The positions for making the splints were as follows: intercuspal position (IP), 3 mm and 5 mm opening positions from the intercuspal position (U3 and U5), and 5 mm right and left position from U3 (UL and UR). The splint for IP was adjusted not to cause occlusal interference at any mandibular positions[14]. Subjects were instructed to lightly occlude, except for NI, for maintaining the mandible positions determined with splints during recording. At the position NI, the subjects wore the same splint as position IP but no instruction of occlusion was given. The subjects were also asked to walk at three gait speeds, fast, ordinary and slow speed.

Prior to this experiment, in order to examine the gait character, the subjects were asked to walk at fast, ordinary and slow speed as usual they does, without wearing splints. Three trials a day for each gait speed

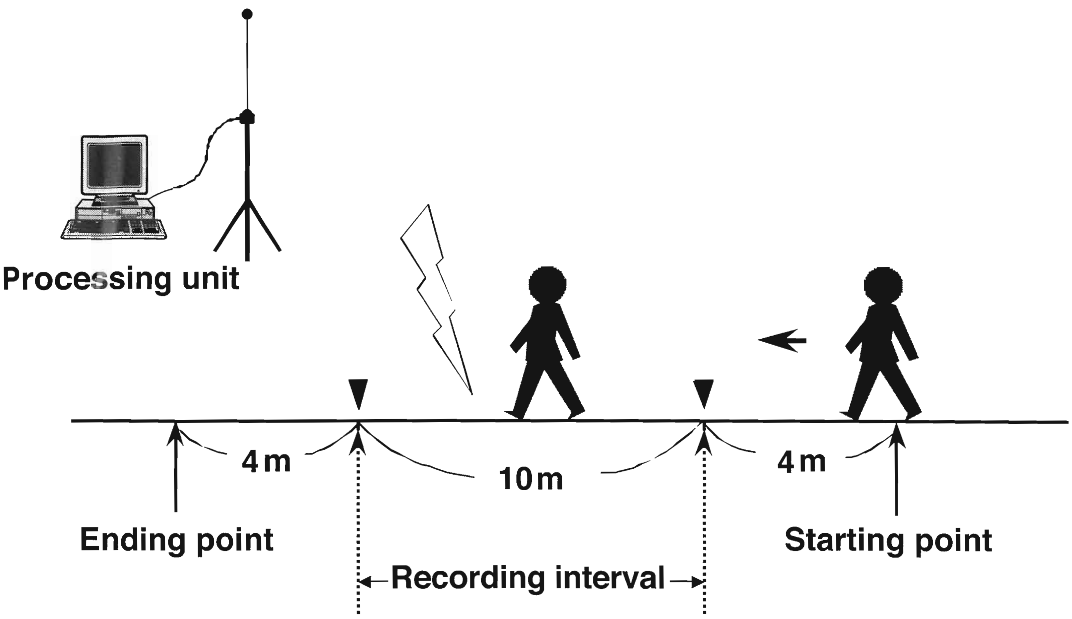

Fig. 2. Scheme of the gait measurements. The electrical signals, which were detected by the strain gauges attached to the shoes, were transmitted to the processing unit. The midst 10m-walk was taken for analysis.

were repeated for three days, totally twenty-seven times for each subject.

When determining the order of the experimental conditions, Six Latin square design was employed so as to distribute the learning effect evenly to each condition. The trials were performed totally eighteen times.

2. Analysis

Gait cycle, coefficient of variation for gait cycle, gait velocity were statistically analyzed at each walking speeds using one-way ANOVA with repeated measures at the 0.05 level of significance. Multiple comparison tests were performed using contrast test to examine the differences between NI and other mandibular positions in these variables.

Results

1. Gait character of the subjects

The gait characters of the twelve subjects were shown in Table 2. Standard deviations of gait cycle and gait velocity were ranged from 6.2 to 13.5% of the means. The means of coefficient of variation for gait cycle and gait velocity were relatively small which were 0.154 and 0.048 respectively.

2. The influence of mandibular positions

Means and standard deviation of gait cycle, coefficient of variation for gait cycle and gait velocity are shown in Table 3, 4 and 5.

As shown in table 6, gait cycle, coefficient of variation and gait velocity were influenced by mandibular position at various gait speed. The gait cycle was significantly influenced by the mandibular position at fast speed, ordinary speed and slow speed ($p=0.002$, $p=0.007$, $p=0.026$, respectively). Coefficient of variation for gait cycle was significantly influenced by the mandibular position at fast speed and ordinary speed ($p=0.011$, $p=0.047$, respectively). Gait velocity was significantly influenced by the mandibular position only at fast speed ($p=0.023$).

Table 7 showed the results of comparisons for gait cycle, coefficient of variation and gait velocity in altered mandibular positions at various gait speed with NI using contrast test. In comparison to NI, gait cycle increased significantly in U3 and UL at ordinary speed ($p=0.035$, $p = 0.042$, respectively), and significantly decreased in U5, UL, and UR at fast speed ($p = 0.024$, $p = 0.015$, $p = 0.004$, respectively) and in UR at slow speed ($p = 0.013$). Coefficient of variation for gait cycle increased significantly in UL, UR at fast speed ($p = 0.030$, $p = 0.018$, respectively) and in IP at slow speed ($p = 0.002$). Gait velocity increased significantly in U5 and UR at fast speed ($p = 0.012$, $p = 0.007$,

Table 2. Gait characteristics of the twelve subjects

Variable		Gait speed Fast	Ordinary	Slow
Gait cycle time (s)	Mean	0.795	0.922	1.086
	s.d.	0.050	0.060	0.110
CV of gait cycle time	Mean	0.173	0.154	0.137
	s.d.	0.020	0.020	0.020
Gait velocity (m/min)	Mean	97.8	77.5	58.8
	s.d.	9.77	8.19	7.96
CV of gait velocity	Mean	0.033	0.050	0.061
	s.d.	0.022	0.036	0.036

CV ; Coefficient of variation

Table 3. Means of gait cycle time and standard deviation

	Mean ± s.d. Fast	Ordinary	Slow
NI	0.814 ± 0.056	0.912 ± 0.076	1.037 ± 0.069
IP	0.793 ± 0.042	0.912 ± 0.065	1.030 ± 0.070
U3	0.790 ± 0.045	0.933 ± 0.056	1.027 ± 0.064
U5	0.786 ± 0.052	0.918 ± 0.060	1.042 ± 0.070
UL	0.775 ± 0.060	0.930 ± 0.063	1.028 ± 0.071
UR	0.777 ± 0.062	0.900 ± 0.065	1.023 ± 0.063

(s)

Table 4. Means of CV for gait cycle time and standard deviation

	Mean ± s.d. Fast	Ordinary	Slow
NI	0.170 ± 0.020	0.165 ± 0.044	0.135 ± 0.018
IP	0.185 ± 0.043	0.166 ± 0.038	0.140 ± 0.017
U3	0.187 ± 0.042	0.150 ± 0.015	0.136 ± 0.016
U5	0.187 ± 0.044	0.163 ± 0.035	0.134 ± 0.018
UL	0.202 ± 0.057	0.149 ± 0.018	0.137 ± 0.015
UR	0.204 ± 0.057	0.176 ± 0.050	0.137 ± 0.014

Table 5. Means of gait velocity and standard deviation

	Mean ± s.d. Fast	Ordinary	Slow
NI	94.542 ± 9.942	76.852 ± 9.967	63.308 ± 9.196
IP	96.033 ± 8.924	76.876 ± 10.035	64.141 ± 9.170
U3	96.612 ± 9.290	75.189 ± 8.670	64.277 ± 8.532
U5	97.146 ± 10.017	76.103 ± 9.204	62.512 ± 8.449
UL	96.711 ± 9.679	75.616 ± 9.405	64.071 ± 8.700
UR	97.484 ± 9.401	76.791 ± 9.505	63.532 ± 8.738

(m/min)

respectively) and significant decrease in U3 at ordinary speed (p = 0.027).

Discussion

Upright posture of human being is physically unstable because the supporting area of the foot base is narrow, the center of body gravity is high located, and the heavy head is positioned on the top of the spinal[15]. The jaw elevating muscles contribute toward supporting the head in proper position as antigravity muscles and control subtly the posture[16], so it is probable that the change of mandibular position would influence the body posture. For the last few decades a considerable number of studies have shown that the change of occlusion affect the head and cervical muscles, leading to changes of the head posture and subsequently modifications of the body[1-5]. These literatures indicate that the alteration of mandibular position would influence on the body equilibrium function, which is concerned in postural control system under static condition, but it has been little known under dynamic condition.

In this study, the gait, which is considered to be one of basic and spontaneous movements in our daily life was adopted, and the relation between the alteration of occlusion and gait stability was investigated. The telemeter system was used for gait measuring so as not to restrain walking. In the preliminary experiments, a little variation was found in gait cycle, gait velocity, and coefficient of variations among the individuals. However, these variations were not problematic for further analysis which was performed on the within-subject comparison. The variations for gait cycle and gait velocity were not dispersed widely within each subject at any walking speeds so that the individual recordings were considered repeatable.

The alteration of mandibular position affected the gait cycle, coefficient of variation for gait cycle and gait velocity. But when the mandible is kept using the splint in the determined position, the influence of occluding may not be ignored. In order to investigate the occluding effect, the gaits in the mandibular position without instruction for occlusion and the mandibular position close to rest position with occlusion were compared aside from this study. As a result, significant difference was not found at any gait speed. It may be concluded that the occluding force, which was needed to lightly keep the mandible in the determined positions, was not large enough to disturb the gait stability. Thus it may be considered that the change of mandibular position caused the strain of head and neck muscles, thereby the body equilibrium was impaired leading to imbalance walking.

Table 6. Results of Repeated measures ANOVA for gate cycle time, CV of gait cycle time and gait velocity at each gait speed

	gait cycle	CV of gait cycle	gait veolcity
mandibular position at fast speed	*	*	*
mandibular position at ordinary speed	*	*	
mandibular position at slow speed	*		

* : Statistically significant($p<0.05$)

Table 7. Results of contrast test comparing the control with other mandibular positions

	gait cycle			CV of gait cycle			gait velocity		
	fast	ordinary	slow	fast	ordinary	slow	fast	ordinary	slow
IP						*			
U3		*						*	
U5	*						*		
UL	*	*		*					
UR	*		*	*			*		

* : Statistically significant($p<0.05$)

For gait cycle, significant influences were found in more conditions compared to the other variables. Generally, when a person changes walking speed on purpose, the speed is controlled by changing gait cycle rather than stride length[17]. Therefore it is conceivable that gait cycle may be easily changed when body equilibrium deteriorates. At the fast speed significant influences were found in more conditions than at the other gait speeds. As walking at the maximum speed reflects the ability or the conditions of the body rather than walking at the ordinary speed[18,19], it may be considered that the body postural control was easily influenced by altering the mandibular position at fast speed gait. The reduction of gait cycle was observed in U5, UR and UL at the fast speed and in UR at the slow speed compared with NI. On the contrary, the increase of gait cycle was found in U3 and UL at the ordinary speed compared with NI. It is probable that these modifications of the gait occurred to compensate for the deterioration of the body balance. It could be considered that the reductions of gait cycle appeared at the fast speed and the slow speed meant recovering the impairment of body equilibrium by stepping faster than usual. However, it is difficult to explain in the same manner about the increase of gait cycle observed at ordinary speed.

The coefficient of variation for gait cycle could be considered as an index indicating the stability of the gait. Significant differences were found in IP at slow speed and UL and UR at fast speed compared with NI. However, significant difference was not found at ordinary speed. It is considered that the ordinary speed is a condition which can cope with any changes during walking. Therefore, at ordinary speed, even when changed mandibular positions would influence body equilibrium, some positive compensation might function and consequently gait stability could be kept at normal level. In the case of fast speed, on the other hand, the deterioration of the body equilibrium caused by the changed mandibular position seemed to appear easily since the fast walking tends to reflect the condition of the body as mentioned before[18,19].

The trials in which gait velocity changed in comparison with NI corresponded mostly to those in which gait cycle changed. It may denote that the stride length nearly did not change.

In this study, it was found that the change of mandibular position would incline to cause influence on the gait stability. These results might lead to the conclusion that the proper restoration of occlusion in prosthodontic treatment is important not only for recovering the masticatry function but also to maintain the body equilibrium function.

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