

## CHAPTER IV

### RESULTS

#### 1. Investigating the effect of the knee electro-orthosis on gait parameters

##### A. Pilot study

##### 1. Participants of the pilot study

For a pilot study, the KEO was controlled using a knee switch sensor. This study was performed on 6 participants (2 women and 4 men with an age mean of  $53.67 \pm 5.79$  years) with hemiplegia (5 with right hemiplegia and 1 with left hemiplegia). The average weight and height of subjects were  $65.67 \pm 13.98$  kg (45 - 86 kg) and  $157.67 \pm 9.31$  cm (150 - 175 cm), respectively. Duration of hemiplegia was  $86.83 \pm 34.83$  days (44 - 128 days), respectively. Demographic information of the participants' pool is presented in Table 6.

Table 6 Demographic information of the pilot participants

Subject	Sex	Age (yr)	Weight (kg)	Height (cm)	Side affect	Duration of hemiplegia (days)	Quadriceps inner strength	FAC
1	M	57	86	175	Rt	73	2	2
2	M	46	70	155	Rt	128	2	3
3	M	55	72	156	Rt	44	3	3
4	M	57	57	160	Rt	104	2	2
5	F	47	64	150	Rt	54	2	2
6	F	60	45	150	Lt	118	2	2

Note: Rt = Right side, Lt = Left side

## 2. Gait parameters of the pilot study

The gait parameters were not significantly different from each other. The results of all gait parameters are presented in Table 7.

## 3. Knee angle of the pilot study

There was no significant difference in the knee angle ( $p=0.513$ ) in different conditions (Table 8).

Table 7 The gait parameters of the pilot study

Parameters	Mean			Pairwise comparison	p-value	
	No KEO	KO	KEO			
Velocity $\pm$ SD (cm/sec)	42.57 $\pm$ 22.94	43.34 $\pm$ 23.16	43.18 $\pm$ 21.46	No KEO – KO	0.311	
				No KEO – KEO		
				KO – KEO		
Cadence $\pm$ SD (steps/min)	70.76 $\pm$ 22.14	70.97 $\pm$ 25.71	72.48 $\pm$ 21.69	No KEO – KO	0.311	
				No KEO – KEO		
				KO – KEO		
Step length $\pm$ SD (cm)	US	29.23 $\pm$ 13.38	30.9 $\pm$ 10.7	29.68 $\pm$ 12.86	No KEO – KO	0.607
					No KEO – KEO	
					KO – KEO	
	AS	38.15 $\pm$ 8.76	37.61 $\pm$ 9.03	37.87 $\pm$ 6.67	No KEO – KO	1.000
					No KEO – KEO	
					KO – KEO	
Swing time $\pm$ SD (sec)	US	0.35 $\pm$ 0.04	0.405 $\pm$ 0.07	0.35 $\pm$ 0.05	No KEO – KO	0.091
					No KEO – KEO	
					KO – KEO	
	AS	0.59 $\pm$ 0.18	0.591 $\pm$ 0.2	0.6 $\pm$ 0.17	No KEO – KO	0.819
					No KEO – KEO	
					KO – KEO	
Stance time $\pm$ SD (sec)	US	1.274 $\pm$ 0.39	1.264 $\pm$ 0.49	1.222 $\pm$ 0.34	No KEO – KO	0.449
					No KEO – KEO	
					KO – KEO	
	AS	1.038 $\pm$ 0.25	1.06 $\pm$ 0.34	0.972 $\pm$ 0.2	No KEO – KO	0.549
					No KEO – KEO	
					KO – KEO	

Note: US = Unaffected side, AS = Affected side, No KEO = Walking without the KEO,

KO = Walking with the KO, KEO = Walking with the KEO

Table 8 The knee angle of the pilot study participants

Parameters	Mean $\pm$ SD			p-value
	No KEO	KO	KEO	
Knee angle (degrees)	182.38 $\pm$ 5.3	179.95 $\pm$ 2.45	178.93 $\pm$ 1.82	0.513

Note: No KEO = Walking without the KEO, KO = Walking with the KO,  
KEO = Walking with the KEO

## B. Main study

### 1. Participants of the main study

The KEO was controlled using the foot switch sensor. This study was performed on 13 participants (4 women and 9 men with an age mean of  $49.46 \pm 7.9$  years) with hemiplegia (11 with right hemiplegia and 2 with left hemiplegia). The average weight and height of the participants were  $61.23 \pm 8.83$  kg (50 - 76 kg) and  $159.54 \pm 5.78$  cm (150 - 174 cm), respectively. Duration of hemiplegia was  $124.69 \pm 54.1$  days (21 - 225 days). Demographic information of the participants' pool is presented in Table 9.

Table 9 Demographic information of the main study participants

Subject	Sex	Age (yr)	Weight (kg)	Height (cm)	Side affect	Duration of hemiplegia (days)	FAC	Quadriceps inner strength
1	M	46	70	155	Rt	156	3	2
2	M	55	72	156	Rt	96	3	3
3	M	33	76	174	Lt	165	3	2
4	M	57	57	160	Rt	153	2	2
5	M	42	55	162	Rt	192	2	3
6	F	47	64	150	Rt	115	2	2
7	M	55	66	160	Rt	88	2	2
8	F	55	70	163	Rt	82	2	2
9	M	54	57	159	Lt	225	2	2
10	F	38	50	160	Rt	21	2	3
11	F	49	55	153	Rt	124	2	3
12	M	59	50	162	Rt	77	2	3
13	M	53	54	160	Rt	127	2	2

Note: Rt = Right side, Lt = Left side

## 2. Gait parameters of the main study

The only swing time of the affected side was significantly different between groups ( $p=0.037$ ). However, the other gait parameters were not significantly different from each other. The results of all gait parameters are presented in Table 10.

## 3. Knee angle of the main study

There was no significant difference in the knee angle ( $p=0.199$ ) in different conditions (Table 11).

Table 10 The gait parameters of the main study

Parameters		Mean			Pairwise comparison	FT	WT
		No KEO	KO	KEO			
Velocity $\pm$ SD (cm/sec)		45.37 $\pm$ 28.13	45.55 $\pm$ 28.45	47.3 $\pm$ 29.26	No KEO – KO	0.584	-
					No KEO – KEO		
					KO – KEO		
Cadence $\pm$ SD (steps/min)		69.99 $\pm$ 25.47	70.84 $\pm$ 25.36	72.78 $\pm$ 25.22	No KEO – KO	0.589	-
					No KEO – KEO		
					KO – KEO		
Step length $\pm$ SD (cm)	US	31.44 $\pm$ 15.01	32.33 $\pm$ 14.8	32.37 $\pm$ 14.37	No KEO – KO	0.500	-
					No KEO – KEO		
					KO – KEO		
	AS	40.63 $\pm$ 11.6	39.08 $\pm$ 10.94	39.92 $\pm$ 11.44	No KEO – KO	0.232	-
					No KEO – KEO		
					KO – KEO		
Swing time $\pm$ SD (sec)	US	0.457 $\pm$ 0.16	0.449 $\pm$ 0.16	0.423 $\pm$ 0.11	No KEO – KO	0.735	-
					No KEO – KEO		
					KO – KEO		
	AS	0.7 $\pm$ 0.34	0.683 $\pm$ 0.36	0.658 $\pm$ 0.28	No KEO – KO	0.037	0.196
					No KEO – KEO		0.039*
					KO – KEO		0.221
Stance time $\pm$ SD (sec)	US	1.527 $\pm$ 0.82	1.498 $\pm$ 0.82	1.461 $\pm$ 0.76	No KEO – KO	0.292	-
					No KEO – KEO		
					KO – KEO		
	AS	1.279 $\pm$ 0.57	1.26 $\pm$ 0.59	1.23 $\pm$ 0.61	No KEO – KO	0.295	-
					No KEO – KEO		
					KO – KEO		

Note: US = Unaffected side, AS = Affected side, No KEO = Walking without the KEO,

KO = Walking with the KO, KEO = Walking with the KEO

FT = Friedman test, WT = Wilcoxon signed ranks test

Table 11 The knee angle of the main study

Parameters	Mean $\pm$ SD			p-value
	No KEO	KO	KEO	
Knee angle (degrees)	177.56 $\pm$ 7.26	176.59 $\pm$ 6.89	177.29 $\pm$ 6.74	0.199

Note: No KEO = Walking without the KEO, KO = Walking with the KO,

KEO = Walking with the KEO

Analyzing the gait velocity of individual patient in the main study revealed that patients with normal knee alignment during stance phase tended to improve the gait velocity when using the KEO. On contrary, those with knee hyperextension showed a reduction in gait velocity when using the KEO. Therefore, the data was divided into two groups according to the knee alignment during the stance phase of the gait cycle. Classification of the participants to each subgroup was based on the knee angle at the mid stance and was measured using the SiliconCOACH<sup>®</sup> Digitizer.

All participants in the main study were divided into two subgroups, the first eight normal knee alignments group and the second five knee hyperextension group. Eight participants (3 women and 5 men with an age mean of  $50.63 \pm 7.19$  years) with hemiplegia (7 with right hemiplegia and 1 with left hemiplegia) had normal knee alignment. The average weight and height of participants were  $57.88 \pm 8.48$  kg (50 - 72 kg) and  $159.38 \pm 3.38$  cm (153 - 163 cm), respectively. Duration of hemiplegia was  $118 \pm 65.37$  days (21 – 225 days). Five participants (1 woman and 4 men with an age mean of  $47.6 \pm 9.48$  years) with hemiplegia (4 with right hemiplegia and 1 with left hemiplegia) had knee hyperextension. The average weight and height of participants were  $66.6 \pm 7.06$  kg (57 - 76 kg) and  $159.8 \pm 8.96$  cm (150 - 174 cm), respectively. Duration of hemiplegia was  $135.4 \pm 32.68$  days (88 - 165 days). The characteristics of the both groups' participants are presented in Table 12.

Table 12 The characteristics of the both groups' participants

Characteristics	Normal knee alignment group	Knee hyperextension group
Number of subjects	8	5
Men / Women	5 / 3	4 / 1
Mean age $\pm$ SD (yr)	50.63 $\pm$ 7.19	47.6 $\pm$ 9.48
Mean height $\pm$ SD (cm)	159.38 $\pm$ 3.38	159.8 $\pm$ 8.96
Mean weight $\pm$ SD (kg)	57.88 $\pm$ 8.48	66.6 $\pm$ 7.06
Duration of hemiplegia (days)	118 $\pm$ 65.37	135.4 $\pm$ 32.68
Affected side Right / Left (case)	7 / 1	4 / 1
FAC level 2 / level 3 (case)	7 / 1	3 / 2
Quadriceps in inner range grade 2 / grade 3 (case)	3 / 5	5 / -

#### 4. The results of normal knee alignment group

##### 4.1 The gait parameters of normal knee alignment group

The results of all gait parameters are presented in Table 13 and Figure 13 - 16.

##### 4.2 Knee angle of normal knee alignment group

There was no significant difference in the knee angle ( $p=0.607$ ) in different conditions (Table 14).

Table 13 The gait parameters of normal knee alignment group

Parameters		Mean			Pairwise comparison	FT	WT
		No KEO	KO	KEO			
Velocity $\pm$ SD (cm/sec)		35.59 $\pm$ 25.82	37.08 $\pm$ 27.03	40.1 $\pm$ 30.09	No KEO – KO	0.030*	0.161
					No KEO – KEO		0.025*
					KO – KEO		0.050*
Cadence $\pm$ SD (steps/min)		61.32 $\pm$ 25.72	64.01 $\pm$ 26.71	67.03 $\pm$ 27.33	No KEO – KO	0.021*	0.050*
					No KEO – KEO		0.017*
					KO – KEO		0.017*
Step length $\pm$ SD (cm)	US	26.36 $\pm$ 14.9	27.44 $\pm$ 14.75	27.7 $\pm$ 14.94	No KEO – KO	0.607	-
					No KEO – KEO		
					KO – KEO		
	AS	38.03 $\pm$ 12.8	36.9 $\pm$ 11.76	38.14 $\pm$ 12.57	No KEO – KO	0.325	-
					No KEO – KEO		
					KO – KEO		
Swing time $\pm$ SD (sec)	US	0.399 $\pm$ 0.1	0.392 $\pm$ 0.11	0.374 $\pm$ 0.08	No KEO – KO	0.325	-
					No KEO – KEO		
					KO – KEO		
	AS	0.844 $\pm$ 0.33	0.81 $\pm$ 0.38	0.748 $\pm$ 0.29	No KEO – KO	0.008*	0.161
					No KEO – KEO		0.012*
					KO – KEO		0.161
Stance time $\pm$ SD (sec)	US	1.888 $\pm$ 0.85	1.815 $\pm$ 0.88	1.73 $\pm$ 0.839	No KEO – KO	0.021*	0.208
					No KEO – KEO		0.036*
					KO – KEO		0.017*
	AS	1.435 $\pm$ 0.66	1.39 $\pm$ 0.71	1.358 $\pm$ 0.74	No KEO – KO	0.206	-
					No KEO – KEO		
					KO – KEO		

Note: US = Unaffected side, AS = Affected side, No KEO = Walking without the KEO,  
 KO = Walking with the KO, KEO = Walking with the KEO

FT = Friedman test, WT = Wilcoxon signed ranks test

Table 14 The knee angle of normal knee alignment group

Parameters	Mean $\pm$ SD			p-value
	No KEO	KO	KEO	
Knee angle (degrees)	173.76 $\pm$ 6.51	173.05 $\pm$ 6.22	174.13 $\pm$ 6.16	0.607

Note: No KEO = Walking without the KEO, KO = Walking with the KO,

KEO = Walking with the KEO



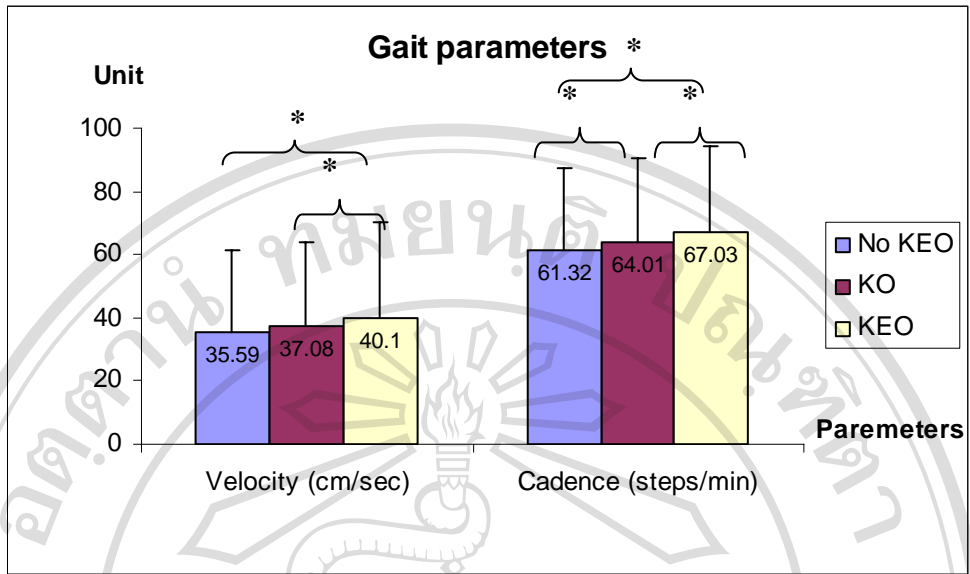


Figure 13 The mean velocity and cadence of normal knee alignment group

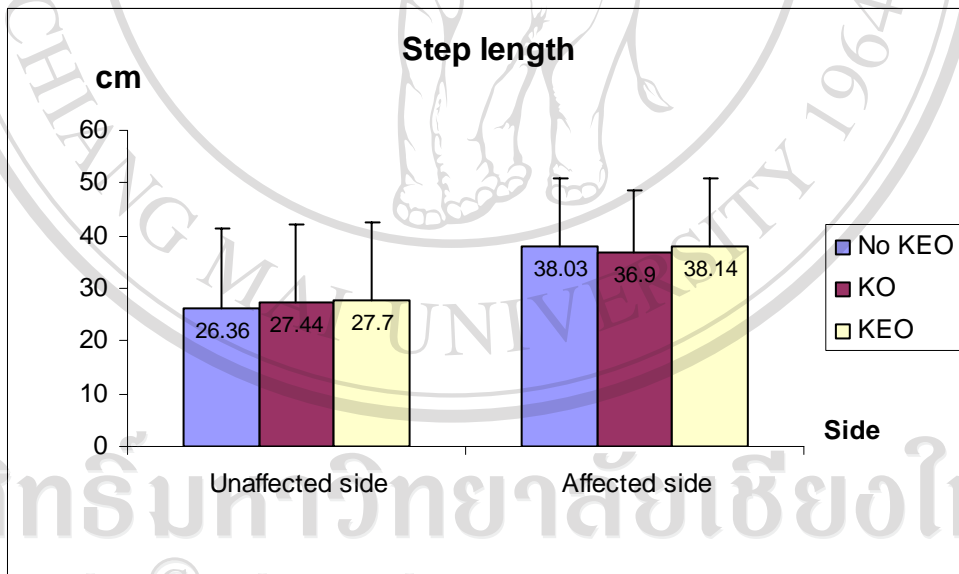


Figure 14 The means of step length of normal knee alignment group

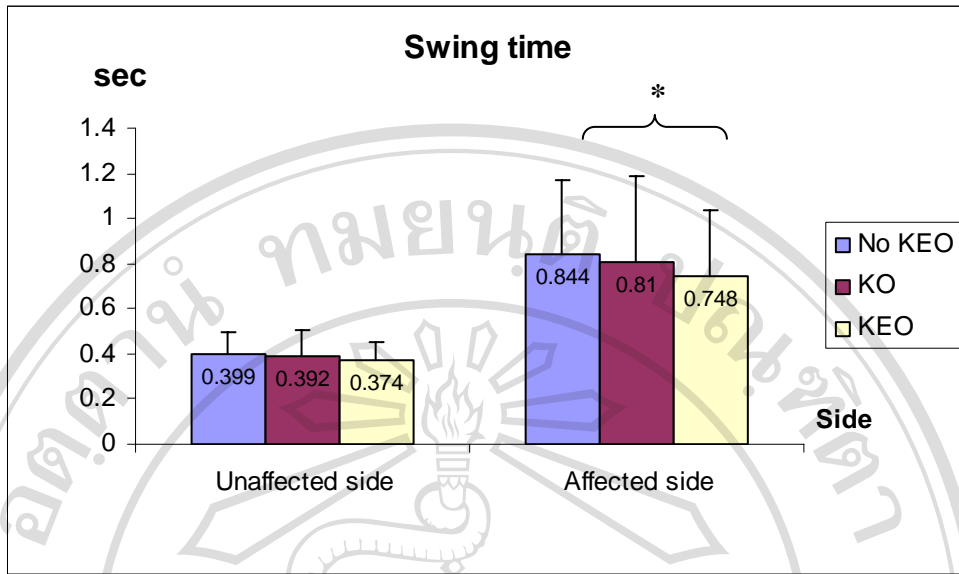


Figure 15 The means of swing time of normal knee alignment group

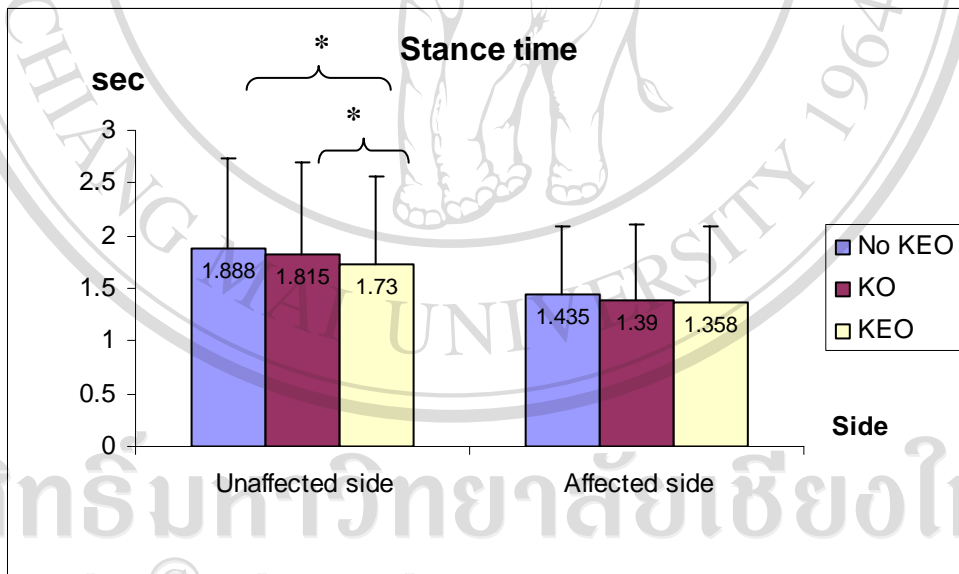


Figure 16 The means of stance time of normal knee alignment group

## 5. The results of knee hyperextension group

### 5.1 The gait parameters of knee hyperextension group

The gait parameters were not significantly different from each other. The results of all gait parameters are presented in Table 15.

### 5.2 Knee angle of knee hyperextension group

There was no significant difference in the knee angle ( $p=0.247$ ) in different conditions (Table 16).

Table 15 The gait parameters of knee hyperextension group

Parameters	Mean			Pairwise comparison	p-value	
	No KEO	KO	KEO			
Velocity $\pm$ SD (cm/sec)	61.02 $\pm$ 26.63	59.1 $\pm$ 27.87	58.84 $\pm$ 30.09	No KEO – KO	0.165	
				No KEO – KEO		
				KO - KEO		
Cadence $\pm$ SD (steps/min)	83.86 $\pm$ 19.93	81.75 $\pm$ 20.94	81.99 $\pm$ 20.73	No KEO – KEO	0.104	
				KO - KEO		
				KO - KEO		
Step length $\pm$ SD (cm)	US	39.57 $\pm$ 12.39	40.16 $\pm$ 12.31	39.84 $\pm$ 10.75	No KEO – KO	0.819
					No KEO – KEO	
					KO - KEO	
	AS	44.78 $\pm$ 9.05	42.58 $\pm$ 9.6	42.77 $\pm$ 9.97	No KEO – KO	0.247
					No KEO – KEO	
					KO - KEO	
Swing time $\pm$ SD (sec)	US	0.55 $\pm$ 0.19	0.541 $\pm$ 0.19	0.502 $\pm$ 0.1	No KEO – KO	0.819
					No KEO – KEO	
					KO - KEO	
	AS	0.471 $\pm$ 0.21	0.479 $\pm$ 0.24	0.514 $\pm$ 0.2	No KEO – KO	0.819
					No KEO – KEO	
					KO - KEO	
Stance time $\pm$ SD (sec)	US	0.95 $\pm$ 0.32	0.99 $\pm$ 0.38	1.03 $\pm$ 0.34	No KEO – KO	0.549
					No KEO – KEO	
					KO - KEO	
	AS	1.031 $\pm$ 0.31	1.051 $\pm$ 0.28	1.025 $\pm$ 0.26	No KEO – KO	0.949
					No KEO – KEO	
					KO - KEO	

Note: US = Unaffected side, AS = Affected side, No KEO = Walking without the KEO,

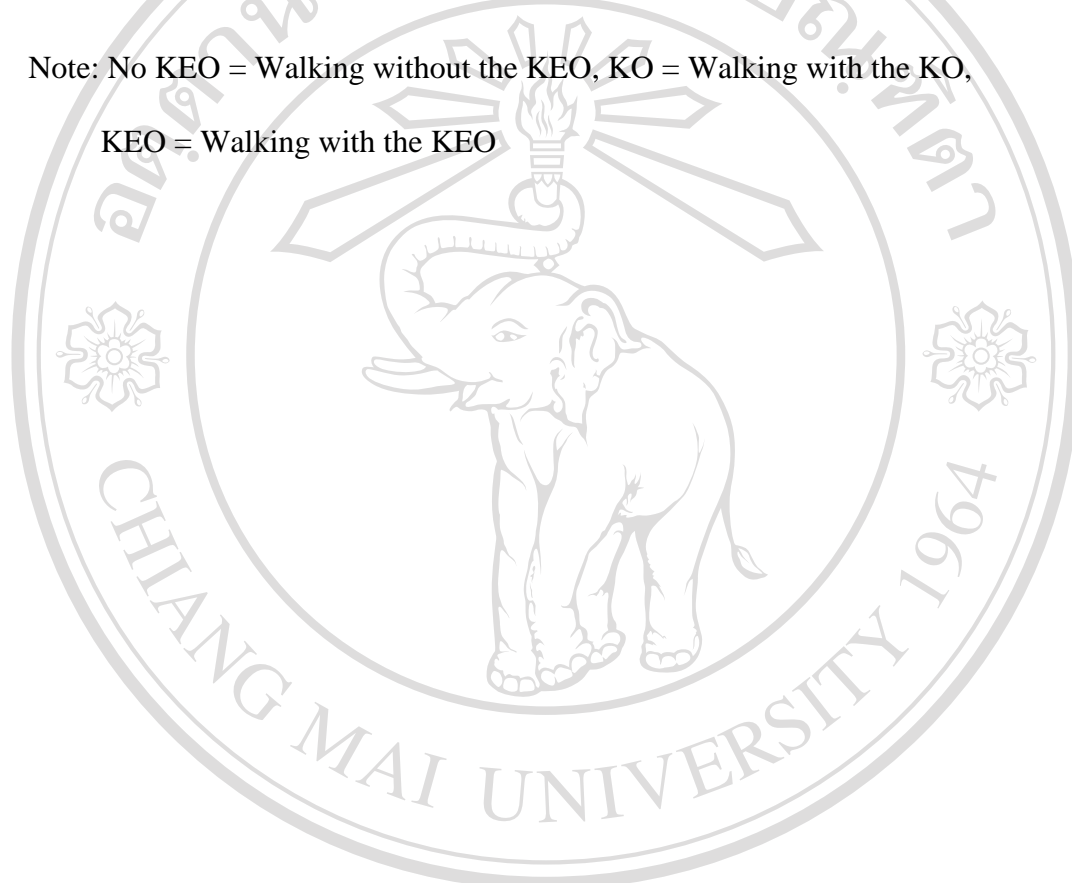
KO = Walking with the KO, KEO = Walking with the KEO

FT = Friedman test, WT = Wilcoxon signed ranks test

Table 16 The knee angle of knee hyperextension group

Parameters	Mean $\pm$ SD			p-value
	No KEO	KO	KEO	
Knee angle (degree)	183.65 $\pm$ 2.94	182.23 $\pm$ 3.07	182.34 $\pm$ 4.22	0.247

Note: No KEO = Walking without the KEO, KO = Walking with the KO,  
KEO = Walking with the KEO



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