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To cite this article: R A Hasbiandra *et al* 2018 *J. Phys.: Conf. Ser.* **1073** 062046

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Effect of contralateral and ipsilateral cane usage on gait symmetry in patients with knee osteoarthritis

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Abstract. Pathological gait in knee osteoarthritis (OA) cause changes in spatial-temporal parameters and result in gait asymmetry. It is not yet known how contralateral and ipsilateral cane usage, assessed through gait spatial-temporal parameters, impacts knee OA. This study assessed gait symmetry and spatial-temporal parameters while ipsilateral and contralateral cane usage in patients with knee OA. Cross-sectional studies on consecutive 50–70-year-old patients with knee OA were conducted. Subjects were asked to walk on a 10-m track with no walking aids, with contralateral cane usage and with ipsilateral cane usage and were recorded with video cameras to assess gait spatial-temporal parameters and symmetry. Forty samples were analysed (mean subject age, 63.5 years); prevalence in women (95%) greater than men (5%), with the most of knee OA is KL III (55%). There were no significant differences in the symmetry ratio between the three conditions. There were significant differences in gait speed, step time, stance phase, swing phase, step length and double support with contralateral and ipsilateral cane usage compared with that without walking aid usage. There was no significant difference in gait symmetry with contralateral and ipsilateral cane usage in patients with knee OA.

1. Introduction

Osteoarthritis (OA) is a heterogeneous group of joint conditions with various causes and similar pathological features. These pathological features occur in the entire joint and include abnormalities of the cartilage, subchondral bone, synovial joint, joint capsule, ligament and muscle tissues. Generally, OA occurs in weight-bearing joints, such as hip, knee and ankle joints [1,2]. Knee OA is the most frequent cause of lower extremity disability among the elderly. Knee OA is estimated to occur in 10% men and 13% women aged ≥ 60 years. The number of patients with OA is expected to increase as the elderly and obese populations continue to increase [3].

Mechanical factors, such as dynamic joint-loading, play a role in pathomechanics of knee OA. The onset and progressivity of knee OA occur because of an excessive load on the knee joint because of an anatomy joint abnormality, joint trauma, obesity, misalignment, joint laxity or decreased proprioception [4,5].



Pathological gait changes in patients with knee OA can be caused by biomechanical changes induced by progression of the disease, degenerative process of connective tissue and joints or a compensatory mechanism caused by the disease process. Characteristic differences in patients with knee OA include variations in spatial-temporal parameters (decreased walking speed, shorter step length and less cadence) and kinetic and kinematic variables [6].

Osteoarthritis Research Society International (OARSI) and the American College of Rheumatology recommend cane usage to patients with knee OA. Cane usage in patients with knee OA aims to reduce the biomechanical load of the lower leg joint [7,8]. Cane usage for 2 months for daily activity by patients with knee OA was found to improve the pain scale, functional ability measured by the Lequesne index and increase distance in the 6-min walk test with cane usage.

Contralateral cane usage results in normal gait pattern and hip rotation is also balanced with the rotation of body and shoulder. Present recommendations for knee OA patients include contralateral cane usage. However, some patients prefer ipsilateral cane usage, resulting in a non-reciprocal gait pattern [9].

Pathological gait in knee OA causes changes in spatial-temporal parameters resulting in gait asymmetry. Symmetry can depict more about function control than only using information of walking speed [10]. In addition, gait pattern symmetry becomes important for rehabilitation because it results in numerous negative consequences for the patient, such as inefficiency, balance control adaptation and musculoskeletal injury risk [11]. However, it is not yet known how the effect of contralateral and ipsilateral cane usage on knee OA assessed through the gait spatial-temporal parameters.

2. Methods

This study used a cross-sectional design through consecutive sampling and included 40 subjects. Subjects included male and female patients with knee OA diagnosed based on clinical and radiology criteria established by the American College of Rheumatology [12] and who were treated at the Polyclinic of Medical Rehabilitation, Cipto Mangunkusumo Hospital, Jakarta, between June 2017 and September 2017. The inclusion criteria included patients diagnosed with knee OA KL ≥ 2 , unilateral or bilateral; aged 50–70 years; able to understand and follow instructions and willing to participate in the study and sign an informed consent form. Exclusion criteria included patients with trauma history or who had already undergone total knee replacement; patients with other musculoskeletal abnormalities in the lower limbs, cardiorespiratory disease, balance disorders or neuromuscular diseases that interfere with ambulatory function; obesity with IMT > 30 and having comorbidities, such as a cognitive or mental disorder, that can result in the patient not receiving instructions properly.

Subjects underwent anamnesis, and a physical examination, including assessment of demographic data (name, age, gender, address, phone number, religion and education level), chief complaints, medical history, MMSE examination, a fall risk assessment and a pain scale for both sides of the knee, was performed by the researchers. The pain scale was expressed using the Visual Analog Scale (VAS). The most painful side of the knee (leg A) was the reference side for the cane usage.

Subjects were educated on how to use the cane on the contralateral and ipsilateral sides and were then asked to walk on a 10-m track with a 2-m preparation area located at each end of the track. To start the testing, subjects were initially asked to walk with no walking aids. During the second and third experiments, subjects were asked to walk with a contralateral and ipsilateral cane after randomisation.

All walking experiments were recorded by the researchers using a video camera. The temporal parameter obtained from each subject was obtained from a video recording, and the symmetric ratio of the gait in each subject without aid usage and with contralateral and ipsilateral cane usage was analysed.

Walking speed, right and left foot step time and stride time were obtained when the patient walked on the track using a multimemory stopwatch with a video recording played at normal speed. Then, the time recorded on the stopwatch was recalled and recorded for each right and left foot step time. The average step length (in m) was not directly calculated, but was calculated with temporal variables, i.e., the speed of walking (m/s) and step time (s).

The calculation of the percentage of each phase in a gait pattern cycle (stance time, double support, swing time and single-limb-support time) was obtained using slow-motion video recording. The assessor started the stopwatch when the heel strike occurs on one of the foot. The lap button was then sequentially pressed with the following conditions: the first round was the interval when the heel strike

occurs on the right foot and the left toe left the floor; this phase was the double-support phase. The second round was the interval between the left toe leaving the floor and the left heel striking the floor; this interval was the single-limb-support period of the right foot or swing phase of the left foot. The third round was started when the left heel struck the floor and ended when the right toe left the floor; this interval was the double-support phase. The fourth round was started when the right toe left the floor and ended when the right heel struck the floor; this interval was the swing time phase of the right foot or single-limb-support phase of the left foot. This cycle was continued for the next phase of strides.

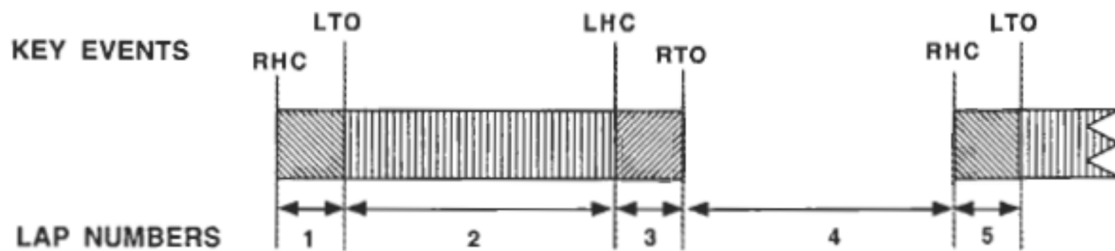


Figure 1. Temporal interval at each phase of the gait pattern with the use of a multimemory stopwatch [13].

The time interval was recorded to the nearest second obtained from the slow-motion video recording as shown in Figure 1 and was used only in the form of a percentage of stride time in each phase. Because the calculation was relative, the percentage value was not affected by the speed of the playback of the video recording; therefore, the time required during each phase of the gait pattern did not require calculation [13].

The symmetry ratio formula for gait pattern was as follows:

Symmetry Ratio:	Swing time of leg A/Stance time of leg A
	Swing time of leg B/Stance time of leg B

The gait pattern was defined as symmetrical if it has a symmetry ratio of 1 ± 0.1 .

Data were analysed using the IBM Statistical Package for the Social Sciences for Windows 20. Results are displayed in narrative and table form. Univariate analysis was the first step of statistical analysis that involved descriptive analysis in the form of description of the characteristic distribution of research subjects. A hypothesis test was performed using the significance value (p). The significance value for hypothesis test was <0.05 with a 95% confidence interval.

3. Results

The total number of subjects included in the analysis was 40 and included 2 male subjects (5%) and 38 female subjects (95%), the subject characteristics are shown in Table 1.

Table 1. Subject characteristics.

Characteristics	Subject Number, n = 40
Age (years old), range (median, max–min)	63,5 (51–69)
Gender, n (%)	
Male	2 (5%)
Female	38 (95%)

Body Mass Index (kg/m ²), range (median, max–min) n (%)	26.45 (22.20–29.58)
Normal	3 (7.50%)
Overweight	10 (25%)
Obesity degree 1	27 (67.50%)
Visual Analog Scale (cm), range (median, max–min)	
A	5 (2–8)
B	3 (0–6)
Knee reference, n (%)	
Right	20 (50%)
Left	20 (50%)
KL Classification, n (%)	
KL II	16 (40%)
KL III	22 (55%)
KL IV	2 (5%)

As demonstrated by a Friedman ANOVA test, there were no differences in the symmetry ratio between the three walking conditions ($p = 0.678$) (Table 2). For parameters of spatiotemporal speed, step length A and step length B, there were significant differences between the three walking conditions. Step time A, step time B, stride time, stance time A, stance time B, swing time A, swing time B and double support were significantly different between without walking aid and with ipsilateral cane usage. Significant differences were also observed between without walking aid and contralateral cane usage, but there were no differences in any parameters between contralateral and ipsilateral cane usage.

Table 2. Spatiotemporal parameters of subjects in three walking conditions.

Parameter	Without walking aids	Contralateral cane usage	Ipsilateral cane usage	p
1. Symmetry ratio	1.030 (0.82–1.610)	1.050 (0.470–1.770)	1.065 (0.67–2.33)	0.678
2. Walking speed (m/s)	0.8553 (0.45–1.11)	0.494 (0.31–0.98)	0.478 (0.29–0.93)	<0.05†
3. Step time (s)				
a. Foot A	0.575 (0.480–0.750)	0.78 (0.56–1.21)	0.755 (0.61–1.18)	<0.05*
b. Foot B	0.560 (0.470–0.860)	0.82 (0.59–1.23)	0.845 (0.59–1.05)	<0.05*
4. Stride time (s)	1.130 (0.980–1.610)	1.645 (1.17–2.44)	1.610 (1.11–2.17)	<0.05*
5. Step length (cm)				
a. Foot A	49.1 (33–66)	43.2 (28–68)	39.6 (26–62)	<0.05†
b. Foot B	48.4 (33–66)	43.4 (23–69)	41.6 (23–61)	<0.05†
6. Stance time (%)				
a. Foot A	68 (63–74)	70 (63–78)	71.47 (61–79)	<0.05*
b. Foot B	68.8 (65–75)	72 (65–83)	71.50 (64–83)	<0.05*
7. Swing time (%)				
a. Foot A	32 (26–37)	29.5 (20–37)	28.5 (21–39)	<0.05*
b. Foot B	31.2 (25–35)	28 (17–35)	28.5 (17–36)	<0.05*
8. Double support (%)	36 (28–47)	42.47 (29–57)	44 (31–55)	<0.05*

*Significant differences were obtained between walking without walking aid and with contralateral and ipsilateral cane in the Friedman ANOVA test.

†Significant differences were obtained between walking without walking aid and with contralateral and ipsilateral cane and between walking with contralateral and ipsilateral cane in the Friedman ANOVA test.

4. Discussion

OA is a significant source of pain and disability and is the most prevalent joint disorder in the elderly. Importantly, knee joints OA are the most commonly experienced form of OA, resulting in impaired mobility and quality of life. Several factors contributing to the development of OA among the elderly are degenerative processes in the ligaments and meniscus, an increased rate of bone turnover and calcification of the joint tissue [14].

Factors related to the occurrence of osteoarthritis in the elderly, include overweight (OR 1.98), obesity (OR 2.66), female gender (OR 1.68) and knee injury history (OR 2.83) [15]. In addition to knee injury history, these factors are evident in most subjects.

The study subjects included 2 male patients (5%) and 38 female patients (95%). The gender factor on the prevalence and severity of knee OA is known. Subjects of this investigation are representative of patients with OA treated at the RSCM Medical Rehabilitation Clinic throughout 2016 among whom 80% patients were female. A recent meta-analysis revealed that women are at greater risk for knee OA than men, and this disparity increases after patients are aged ≥ 55 years. Factors that contribute to a greater occurrence of knee OA in women include hormonal effects and anatomical differences in knee joints [16].

Overweight and obese individuals are also at a greater risk of developing knee OA (RR 2.45 and 4.55). The risk for knee OA incidence increases by 35% for every 5 kg/m² increase in IMT. Furthermore, obesity is an independent predictor of the risk of developing knee OA regardless of the study design, country variables, sample number, gender proportion and knee injury history. The high incidence of knee OA in obese individuals is not only caused by mechanical factors because of excessive loading effects on the joints but also because the fat tissue is known to be an endocrine organ that produces adipokines and cytokines that can trigger low-grade systemic inflammation [17].

Based on the severity of knee OA according to KL classification, 16 (40%), 22 (55%) and 2 (5%) subjects had KL II, KL III and KL IV, respectively. The number of subjects with KL IV knee OA was low because of they could not meet the inclusion criteria due to difficulty in walking without a walking aid.

All participants in this study were diagnosed with knee OA, with the right and left knees reserved as reference sides divided evenly by 20 (50%). Knee OA is known to be an asymmetrical pathological condition. In a previous prospective study that analysed the progress of patients with knee OA over 12 years, 24/30 patients (80%) with unilateral knee OA still had bilateral knee OA after the 12-year period.[18] In another study, the progression and severity of KL in knee OA could play a considerable role in the disease after just 2 years of exposure [19]. However, Marmon et al. found that functional abilities in groups with unilateral and bilateral knee OA were similar [20].

Changes in gait pattern mechanics in patients with knee OA reduces pain in the knee joint and, when the pain is reduced, the gait pattern of patients with knee OA becomes similar to that of patients in the non-pain control group. The mechanism of compensation is speculated to revolve around reducing the pressure and load on the knee joints, which changed kinematics of walking and gait pattern phase and decreased walking speed and stride length [21].

The average walking speed without a walking aid in this study was 0.85 m/ s. This may be due to a higher proportion of male subjects than that in the present study. According to a study by Bohannon et al. gender correlates well with normal walking speeds, particularly in individuals in their 60's, and although this correlation is not significant, a statistically significant correlation is obtained when walking at maximum speed [22].

In the study by Vitton et al., the double-support period in subjects with knee OA was longer than that in subjects in the control group. More specifically, the double-support phase was longer when the limbs involved acted as limbs that precede or as limbs that were left behind [23]. In this study, the double-support phase occurred for 36% of the total gait pattern cycle, whereas in the normal adult gait pattern, the double-support phase lasted for 20% cycle of the gait pattern. This longer double-support period was one of the strategies used for reduce the loading force placed on the knee.

In unilateral knee OA, a short stance and shorter single-limb-support time were observed on the afflicted limb side. This was in accordance with clinical observations where patients with unilateral knee OA often limp with a shorter stance phase in the involved limbs. This asymmetry becomes more noticeable in patients with knee OA with more severe KL degree [24]. Spatiotemporal parameters indicating severity of knee OA include stride length and cadence, where a shorter stride length and lower cadence indicate severe knee OA [25].

There were gender differences for some of the spatiotemporal parameters measured. Specifically, males and females have different gait patterns, although the walking speed, number of cadences and step lengths have been normalised. Men walked with shorter stance and double-limb-support phases along with longer swing and single-limb-support phases than women. In this study, there were only two male subjects; therefore, comparison could not be done [26].

In the present study, there was no significant difference in ratios of gait pattern symmetry between without walking aid, with ipsilateral cane or with contralateral cane usage. However, the number of asymmetric gait patterns increased when patients walked with the ipsilateral cane compared with that when patients walked with the contralateral cane. Compared with walking without a walking aid, that with a contralateral and ipsilateral cane significantly affected spatiotemporal parameters. There were significant differences in parameters of walking speed, step time, stance phase, swing phase, step length and double support with contralateral and ipsilateral cane usage compared with those without walking aid usage. In the study by Fang et al., there were significant differences in temporal parameters (walking speed and cadence) but no significant difference in spatial parameters [9]. Walking speed was significantly slower with contralateral and ipsilateral cane usage than without walking aid usage. However, there was no significant difference between ipsilateral and contralateral cane usage on step time, stance phase, swing phase and double-support time. The decrease in walking speed in this study was likely due to a decrease in step length during contralateral and ipsilateral cane usage.

The decrease in walking speeds due to cane usage can be caused by the need to pay attention to the cane, increased proprioception requirements and optimal cane emphasis on the ground. Cane usage could be a difficult task for some individuals because it is a dual-task condition, and when a patient is not used to cane usage, it will require careful attention to avoid tripping [9,27]. Reaction time was significantly slower in patients who walked with aids while performing a dual-task than in those who walked without walking aids [28]. Only a small number of subjects had ever used a cane in this study, and the cane was not routinely used. However, the walking cane was not used in a proper manner.

The elderly have a decreased ability to maintain postural stability when faced with activities that require high levels of attention and cognition. In the study by Mann et al. nearly half of the elderly prescribed a cane as a walking aid mentioned that the cane was difficult to use and increased the risk of falling [29]. In this study, the average age of participants was 63.5 years; this could be a factor that plays a role in the description of spatiotemporal parameters of gait pattern on the three walking conditions.

Placing and holding the cane on the ground when walking not only lowers the load placed on the supporting legs but also requires additional time, which changes temporal parameters of gait pattern. In this study, the amount of pressure applied to the ground surface by the cane could not be evaluated, even though the subject had been instructed to place no more than 20% of his/her body weight. In the study by Simic et al. there were no differences in the walking speed and stride length in subjects with OA with contralateral cane usage with an emphasis on varied cane pressures of 10%, 15% and 20% body weight [30].

In this study, the walking speed and step length with ipsilateral cane usage were significantly slower and shorter than with contralateral cane usage. Walking is an automatic process, although it can also be consciously controlled. The Central Pattern Generator plays an important role in this automatic control and works not only to control the movement of the lower limbs but also to control rhythmic movements of the arms when walking. The arm swings move in opposite directions with the rotation of the limbs on the contralateral side, and this action probably reduces angular momentum on the body and converts energy into forwarding energy. Other studies have shown that arm swing improves stability when walking, particularly when there is a perturbation or walking abnormality [31].

An investigation by Eke-Okoro et al. revealed that the natural arm swing when walking had a positive impact on walking speed and stride length compared with walking conditions with arms tied to the body [32]. Furthermore, in a study by Ma et al. arm swing exercises in patients with hemiplegic stroke resulted in a significant improvement in distance covered during a 6-min walking test and increased the walking speed during a 10-m walking test [33].

In a study by Vargo et al. contralateral and ipsilateral cane usage showed different activation patterns of the gastrocnemius, hamstring and quadriceps. This pattern of muscle activation was also influenced by the amount of pressure applied to the ground under both conditions. The study also revealed that contralateral cane usage did not fully decrease activation of muscles acting on the knee joint and improved medial hamstring activation when the application of pressure was maximised [34].

This study only analyses the immediate effect of ipsilateral and contralateral cane usage on spatiotemporal parameters and gait pattern symmetry. Long-term evaluation to determine the effects of cane usage on gait pattern spatiotemporal parameters should be the focus of future investigations. Fang et al. investigated patients with pelvic OA and found that relative to the initial conditions, changes were

observed in spatiotemporal parameters of the patients after 4 weeks of cane usage. These results indicate that continuous cane usage may result in improved balance, and therefore, patients with pelvic OA may walk at the same rate as they did before cane usage was initiated [27].

In the present study, majority of the studied patients were afflicted with knee OA KL 2–3; therefore, different results may be obtained in patients with knee OA KL 4. In addition, most of the subjects included herein were female; therefore, results should be interpreted with caution when assessing male patients. Advantages of this study include analysis of gait pattern spatiotemporal parameters using video imagery and simplicity of the study design, which included easy-to-acquire items, such as a multimemory stopwatch.

5. Conclusion

In patients with knee OA, there were no significant differences in gait pattern symmetry following contralateral or ipsilateral cane usage. There were significant differences in walking speed, step time, stride time, step length, double support between without walking aid and with contralateral and ipsilateral cane usage. Furthermore, there were significant differences in step length between contralateral cane usage rather than with ipsilateral cane usage.

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