CLINICAL SCIENCE

ENERGY EXPENDITURE DURING CANE-ASSISTED GAIT IN PATIENTS WITH KNEE OSTEOARTHRITIS

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OBJECTIVE: To compare the energy expenditure in patients with unilateral knee osteoarthritis while walking with canes of different lengths.

METHODS: A quasi-experimental study (single-group) was carried out on thirty patients with unilateral knee osteoarthritis. An adjustable aluminum cane was used, and three different cane lengths were determined for each subject: C1 – length from the floor to the greater trochanter; C2 – length from the floor to the distal wrist crease; and C3 – length obtained by the formula: height x 0.45 + 0.87 m. Resting and walking heart rates were measured with a Polar hear rate meter. Walking speed was calculated by the time required for the patient to walk 10 m. Gait energy cost was estimated using the physiological cost index, and results were compared.

RESULTS: The sample consisted of 25 women and five men (average age of 68 years). Statistically significant differences in physiological cost index measurements were observed between unassisted walking and assisted walking with a cane of any length ($p<0.001$), as well as between walking with a C2-length cane and unassisted walking, and walking with a C1-length cane and walking with a C3-length cane ($p=0.001$; $p = 0.037$; $p=0.001$; respectively).

CONCLUSION: These data demonstrate that small alterations in the length of canes used for weight-bearing ambulation in patients with unilateral knee osteoarthritis increase the energy expenditure measured by the physiological cost index during walking. Further studies are needed for a more precise quantification of the increase in energy expenditure during cane-assisted gait and an assessment of the effectiveness of cane use in relieving pain and improving function in patients with knee osteoarthritis.

KEYWORDS: Walking aids. Energy consumption. Gonarthritis.

INTRODUCTION

Osteoarthritis (OA) is the most common joint disease worldwide, and is characterized by progressive alterations in joint cartilage and substantial regenerative changes due to the formation of new subchondral bone (osteophytes and sclerosis).[1] Patients with knee osteoarthritis normally present with gait changes as a result of muscle weakness, pain, joint deformity and joint instability, leading to gait instability and increased energy requirements for walking. This, in turn, increases fatigue and muscle weakness.[2]

Canes are commonly prescribed on an outpatient basis. The main functions of these mobility aids are to increase the support base, improve balance, and share the body weight load with the upper limbs, which is achieved by directly applying force to the handle of the cane. Canes also increase patient confidence in the performance of daily activities and reduce the risk of falls[3] that is an important issue in the elderly population.[4] Patients with knee OA frequently have to use canes during walking to improve gait, reduce stress on the joints, and spare the contralateral side, which is normally overloaded.[5,6]

Of the many types of canes available, wooden and adjustable aluminum canes are among the most widely used.[7,8] The cane handle is also important and should be selected primarily on the basis of patient comfort and the capacity to provide an adequate surface for effective weight transfer from the upper limbs to the ground. The handle should permit the weight to be conveyed to the center of the cane, thereby increasing the support base and improving the patient's balance.[3] Different methods have been used to estimate the appropriate length of a cane. Measurements of cane length from the floor to the

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greater trochanter of the femur or from the floor to the distal wrist crease are the most common methods used. Cane length can also be determined by the formula: Height of the Individual (meters) x 0.45 + 0.87 m.[9]

Canes are normally used on the contralateral side, and during walking, the affected lower limb is advanced together with the contralateral upper limb carrying the cane following the normal gait pattern.[3] However, the use of a contralateral cane has not yet been proven to be the best approach. In cases of continuous pain or diseases affecting both sides, the use of an ipsilateral cane might be indicated, but these cases should be carefully evaluated in order to identify the most beneficial side for the patient.[10]

To our knowledge, no studies have yet been conducted to determine the effect of cane use on energy expenditure in patients with knee osteoarthritis. The objective of the present study was to compare energy expenditure in patients with unilateral knee osteoarthritis during walking with canes of different lengths.

PATIENTS AND METHODS

Thirty patients with unilateral knee osteoarthritis were consecutively selected from the Rheumatology Outpatient Clinics and were invited to participate in this study. Knee osteoarthritis was classified according to the clinical and radiographic criteria of the American College of Rheumatology.[11] Patients with other rheumatic or osteomuscular diseases in the lower limb or upper limb that would handle the cane were excluded from the study, as well as patients who had prior experience with canes. The study was approved by the Ethics Committee, and patients who fulfilled the criteria were evaluated. Height, weight, OA classification through X-ray analysis, duration of osteoarthritis, dominance, affected side, presence of pain and crepitation, knee and elbow range of motion, cane length, resting heart rate (RHR), walking heart rate (WHR) and walking velocity (WV) were determined for all patients.

An adjustable aluminum cane equipped with a telescopic system was used, and the cane length was determined for each individual as follows: Cane 1 (C1) - from the floor to the greater trochanter; Cane 2 (C2) - from the floor to the distal wrist crease; and Cane 3 (C3) - using the formula L = H x 0.45 + 0.87 m.[8] The elbow flexion angle provided by each cane was determined with a goniometer.

Gait was analyzed in the Gait Laboratory, where the patient was instructed to grip the cane with the contralateral hand and follow a normal gait pattern. RHR was measured with a Polar Heart Rate Monitor – A3 (Polar Electro Oy - Finland). The patient was then asked to walk at their normal gait velocity 10 times over a distance of 10 m, and WHR was recorded each time the patient crossed a line marked at the center of the course. WHR was measured during walking without a cane (WWC) as well as walking with C1 (WC1), walking with C2 (WC2) and walking with C3 (WC3), providing the mean of 10 WHR measurements for each variable. The patient rested for 10 min between measurements to allow the heart rate to return to baseline. The results of these 10 measurements were used to calculate the mean velocity. Based on these data, gait energy cost was estimated using the physiological cost index (PCI),[12] which was calculated according to the formula PCI = (WHR – RHR)/WV, and the results were compared among groups. Data are presented as mean and standard deviation or percentage when appropriate. Differences between measurements were tested by the Student's *t*-test. The significance level was set at $p < 0.05$.

RESULTS

The sample consisted of 25 women (83.3%) and five men (16.7%), ranging in age from 48 to 92 years, with an average age of 68 years. Based on the criteria of the American College of Rheumatology,[11] most patients (76.6%) had Grade II and Grade III osteoarthritis. Symptom duration ranged from three months to 20 years. All patients were right-handed, but 53.3% had osteoarthritis in the left knee. Pain was reported by 93.3% of the patients, and crepitation was present in 96.7%. The clinical characteristics of this population are summarized in Table 1.

Table 1 - Clinical characteristics of patients with knee osteoarthritis (OA)

Sex (n)	Female	25
	Male	5
Age / years (Mean ± SD)		65.7 ± 9.2
OA grade (n)	1	5
	2	14
	3	9
	4	2
Duration of OA / years (Mean ± SD)		6.3 ± 5.8
Dominance (n)	Right	30
	Left	0
Affected side (n)	Right	14
	Left	16
Pain (n)	Yes	28
	No	2
Crepitation (n)	Yes	29
	No	1

Mean cane length was 83.1 cm for C1, 78.6 cm for C2, and 79.7 cm for C3, with a significant difference observed between C1 and the other cane lengths ($p < 0.001$), and no significant difference between C2 and C3 ($p = 0.148$). The elbow flexion angle that these cane lengths imposed averaged

37.6º for C1, 28.3º for C2 and 29.3º for C3, with a significant difference again observed between C1 and the other cane lengths ($p < 0.001$), while no statistically significant difference was found between C2 and C3 ($p > 0.999$).

Table 2 displays RHR, WHR, WV, and PCI measurements during walking with and without canes. No statistically significant differences were found in RHR measured before WWC and before walking with the different canes (WC1, WC2 and WC3). WHR differed significantly between WWC and walking with canes ($p < 0.001$), whereas no difference was observed in WHR among WC1, WC2 and WC3. Significantly higher WV was observed in patients walking without canes than that of patients walking with canes ($p < 0.001$), while no difference in WV was observed among WC1, WC2 and WC3 ($p = 1.000$). Mean PCI obtained during walking was 0.17 for WWC, 0.28 for WC1, 0.25 for WC2, and 0.28 for WC3 (Figure 1). Significant differences in PCI were observed between WWC and the other measurements ($p < 0.001$), and between WC2 and the other measurements (WWC, $p = 0.001$; WC1, $p = 0.037$; WC3, $p = 0.001$), while no difference in PCI was observed between WC1 and WC3 ($p > 0.999$).

DISCUSSION

These results demonstrate that small changes in the length of canes used for walking in patients with unilateral knee osteoarthritis can increase energy expenditure, suggesting that special attention should be given to the use of mobility devices in this population. The cane length in the present study could not be fixed to an exact length, so the cane was adjusted as close as possible to the desired length.

Table 2 - RHR, WHR, WV and PCI measurements (mean ± SD) for patients with knee osteoarthritis while walking with and without canes

resting heart rate (beats/minute)	WWC	77.1 (10.1)
	WC1	77.3 (10)
	WC2	78.1 (9.9)
	WC3	77 (9.4)
walking heart rate (beats/minute)	WWC	85.2 (9.8) * □ ×
	WC1	88.1 (9.9)
	WC2	87.7 (9.6)
	WC3	87.8 (9.8)
walking velocity (meters/minute)	WWC	46 (9.6) * □ ×
	WC1	38.4 (7.4)
	WC2	38.6 (6.8)
	WC3	38.6 (6.4)
physiological cost index (beats/meters)	WWC	0.17 (0.07) * □ ×
	WC1	0.28 (0.10) ° •
	WC2	0.25 (0.10) ∝ × ∇
	WC3	0.28 (0.10) ° ϕ

WWC = walking without cane; WC1 = walking with a cane length to the greater trochanter; WC2 = walking with a cane length to the distal wrist crease; WC3 = walking with a cane length obtained by the formula: Length = Height x 0.45 + 0.87 m; * $p < 0.01$ compared to WC1; □ $p < 0.001$ compared to WC2; × $p < 0.01$ compared to WC3; ° $p < 0.01$ compared to WWC; • $p < 0.05$ compared to WC2; ∝ $p < 0.05$ compared to WC1; ∇ $p < 0.05$ compared to WWC; ϕ $p < 0.01$ compared to WC2.

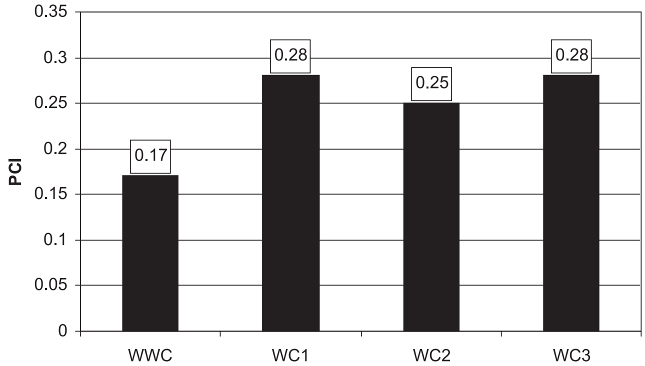

Figure 1 - Mean energy expenditure (Physiological cost index – PCI) in patients with knee OA while walking without a cane (WWC), walking with a cane length to the greater trochanter length (WC1), walking with a cane length to the distal wrist crease (WC2) and walking with a cane length obtained by the formula: individual height x 0.45 + 0.87 m (WC3)

The desired elbow flexion angle reported in the literature for cane use is estimated to be between 20 and 30 degrees.[8] In the present study, C2 and C3 allowed elbow flexion angles similar to these values, although angles between 30 and 40 degrees were also observed with these cane lengths in some patients. The C1 cane length was furthest from the desired angle of elbow flexion and was also the only cane length that permitted an elbow flexion angle between 40 and 50 degrees, which is usually not recommended for a weight-bearing cane.

RHR did not differ significantly among the four time points studied. This suggests that the resting time between each walk was sufficient, which is important for excluding any HR influence on the PCI calculation. We found that WHR was significantly higher while walking with a cane than without a cane. This can be explained by the greater effort associated with walking with canes, especially in patients that have not had an adaptation period.

We observed a statistically significant reduction in WV during walking with the different canes (WC1, WC2 and WC3) as compared to WWC. We believe that one of the reasons for this is that this was the patients' first experience with a cane, and that this could have been avoided by the introduction of a period of adaptation to the cane. In the present study, patients were instructed to walk at their normal velocity; however, some authors have suggested the establishment of a gait speed, since this velocity has a linear relationship with energy expenditure.[13,14] Pagliarulo et al.[15] reported that during walking with canes and prostheses, energy expenditure was lower when the patient was allowed to walk at a self-selected velocity than when stimulated to achieve a target velocity. Nonetheless, this phenomenon probably did not influence our results, as patients were tested in four different situations.

The PCI obtained for WWC was lower than that observed for walking with canes, regardless of cane length. This result clearly demonstrates that cane use increases energy expenditure in patients with knee osteoarthritis. Several authors have reported that canes used for weight-bearing ambulation lead to greater energy expenditure,[16-20] but none of these studies were carried out on patients with knee OA. The PCI index is a low technology technique that has been proposed as an alternative to the measurement of VO_2, due to the linear relationship between HR and oxygen consumption during submaximal exercise.[21-24] Accordingly, some authors have demonstrated that VO_2 and PCI yield comparable results.[12,23,25,26]

The comparison of the three methods used for the choice of cane length revealed that C2 was associated with the lowest energy expenditure, even though C2 was similar to C3 in length. The small size of this sample probably prevented the detection of statistically significant differences in energy expenditure associated with cane length.

These findings are in contrast with those obtained by Mullins and collaborators,[27] who suggested that, within certain limits, cane length does not modify energy expenditure during gait. However, that study was conducted on healthy individuals, so their results may not apply to individuals with gait motor disturbances. We therefore believe that cane length should be taken into account for patients with knee osteoarthritis in order to minimize the increase of energy expenditure during gait. Only a few studies have analyzed energy expenditure during cane-assisted walking, and to our knowledge, none have involved patients with knee osteoarthritis. This prevents any comparison of the present results with those in the literature.

These data demonstrate that small alterations in the length of canes used for weight-bearing ambulation in patients with unilateral knee osteoarthritis increase the energy expenditure (PCI) during walking. Further studies are needed for a more precise quantification of the increase in energy expenditure during cane-assisted gait, along with an assessment of the effectiveness of cane use in reducing pain and improving function in patients with knee osteoarthritis.

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