ASSESSMENT OF WALKING BEFORE AND AFTER UNICOMPARTMENTAL KNEE ARTHROPLASTY

A Comparison of Different Methods

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ABSTRACT. Walking ability was assessed in twenty patients before and one year after knee replacement with a cemented unicompartmental, Brigham prosthesis (mean age 63.4 years, nine women). All patients had moderate medial gonarthrosis. One year after surgery, knee function, assessed by the BOA score, self-selected and maximal walking speed as well as single limb support of the involved leg were increased. Pain and exertion during walking and oxygen cost of level walking were decreased at all measured speeds. Individual improvement in self-selected walking speed was correlated to improvement in maximal walking speed. Individual decrease of oxygen cost of level walking was correlated to decrease of perceived pain and exertion during walking. For clinical routine purpose clinical assessment, especially of pain, supplemented with measurement of self-selected walking speed were found to be sufficient for assessing effects of treatment such as unicompartmental prosthetic knee replacement.

Key words: gait, knee replacement, oxygen consumption, pain, correlations.

Average free walking speed and duration of single limb support to identify weight bearing capability have been pointed out as particularly noteworthy indicators of a patient’s walking ability after total knee replacement (TKR) (7, 9, 15, 16). As many gait parameters are velocity dependent, it is important to clarify whether a change of a gait parameter is due to the change in walking speed or to a change of gait pattern. This is achieved by evaluating the gait variables at a constant walking speed (4). A different method to evaluate walking ability is to study the energy cost of level walking. It has been shown that measurements of both walking speed and oxygen cost of walking are valuable parameters in the assessment of walking both in normal subjects and in patients with walking disorders (6, 8, 10, 11, 12, 13, 20).

Knee arthroplasty has become a common operation and the number of operated patients is increasing every year. To be able to supplement the clinical examinations with tests of walking ability for routine purpose, we have to find simple tests of walking with high correlations to objective, reliable measurements of walking ability. We have not found any report of results after joint replacement in which different methods to study walking capacity have been compared or related to clinical scoring.

The aim of this study was (a) to evaluate individual changes in clinical parameters, assessed by a clinical score, gait parameters and walking efficiency after knee arthroplasty in patients with moderate gonarthrosis and (b) to compare the results from simple walking tests with those from advanced gait analyses.

SUBJECTS AND METHODS

Twenty patients (eleven men and nine women) with moderate gonarthrosis of one knee, grade 2-3 according to
Table 1. Clinical scoring and simple tests of walking ability

<table>
<thead>
<tr>
<th>Score Category</th>
<th>Before Surgery</th>
<th>One year after surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICA score (points)</td>
<td>30.4±2.9</td>
<td>38.1±1.1</td>
</tr>
<tr>
<td>Self-selected walking speed (m·min⁻¹)</td>
<td>62.3±8.3</td>
<td>74.2±5.9</td>
</tr>
<tr>
<td>Maximal walking speed (m·min⁻¹)</td>
<td>85.1±3.9</td>
<td>93.9±9.6</td>
</tr>
<tr>
<td>Pain (1–10) during walking</td>
<td>4.4±2.6</td>
<td>0.8±1.4</td>
</tr>
<tr>
<td>Maximal speed</td>
<td>4.4±2.5</td>
<td>1.8±1.3</td>
</tr>
<tr>
<td>Speed = self-selected speed</td>
<td>3.6±2.2</td>
<td>0.9±1.3</td>
</tr>
</tbody>
</table>

Advanced tests of walking ability

**Gait analysis.** One year after surgery the patients had improved their average self-selected walking speed with 9.8±7.0 m·min⁻¹ (p < 0.001). The ratio between the involved and uninvolved leg in single limb support and vertical force impulse had increased towards normal value (±1) (Table II). In all patients it was possible to find one gait run performed in the same walking speed on both occasions. When walking speed was thus treated as an independent variable, only duration of single limb support demonstrated a significant increase (Table III).

**Walking efficiency.** One year after surgery all patients had increased their average self-selected walking speed with 9.8±7.0 m·min⁻¹ (p < 0.001) during both self-selected and maximal walking speed. Oxygen cost of walking at self-selected walking speed was postoperatively decreased to the same level as that for normal subjects at the same speed.

**Relationship Clinical assessment.** Individual improvement in BOA score was correlated with decrease of pain (r=0.44, p<0.05) and with decrease of exertion (r=0.46, p<0.05) during preoperative self-selected walking speed and with decrease of exertion (r=0.49, p<0.05) during maximal walking speed. There was no correlation between the individual improvement of the BOA score and the change of walking speeds, energy cost of walking or stride characteristics.

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**Results**

Clinical assessment

One year after surgery all patients were able to walk independently. They all had an improvement in pain and exertion during walking. The patients were asked to walk for four minutes in a corridor of 20 m, first at a self-selected, comfortable walking speed and after a rest, at their maximal walking speed. Walking speed was determined by a speedometer (m·min⁻¹) (11). At the end of every walking test the patients were asked to grade their pain and exertion during walking using a ten graded scale (1).

Advanced tests of walking ability

**Gait analysis.** Gait analysis was performed on a force plate walkway consisting of three five-meter long, force measuring platforms recording several consecutive steps from both feet during level walking (17).

The following parameters were measured:

- Mean value of the different gait parameters as presented in Tables I, II, and III.
- Simple tests of walking ability: Self-selected walking speed was measured using six 1 m·min⁻¹ and one 1.5 m·min⁻¹ in the 19 out of the 20 patients. The patient who had an injury, as described above, did not improve.
- Maximal walking speed is presented in Table I. Two patients decreased their maximal walking speed. One of them, the patient who reported the injury, decreased 2.8 m·min⁻¹. The other patient decreased 4.4 m·min⁻¹ but he could already walk very fast preoperatively (109.2 m·min⁻¹). One year after surgery all patients experienced decreased pain during walking at the speed that was self-selected preoperatively (p<0.001) and 16 patients walked without any pain.
- Pain during maximal speed walking was decreased in 19 patients (p<0.001) and 12 patients walked with no pain.
- One year after surgery all patients walked at a speed that was self-selected preoperatively with decreased exertion (r=0.41, p=0.01). At a speed equal to 10 patients experienced decreased exertion during walking (p=0.001).

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Abdik's classification (1), were tested before and on one year after unicompartmental knee replacement. Mean age was 63±4.5 (mean ± SD) years and mean weight was 82±13.5 kg.

All patients were free from symptoms from other joints in the lower extremities and no patient had cardiorespiratory symptoms. None of the patients required any assistive devices for walking.

A unicompartmental endoprosthesis, Brigham model, was used to replace the medial knee compartment (19). A paramellar retinacular incision was used. Femoral and tibial components were cemented in position with soft tissue tightening and any varus deformity was corrected. Weight bearing and exercises were started on the first postoperative day and after discharge all patients had the same physiotherapy postoperatively twice a week, in all ten times.

**Clinical assessment**

All patients were clinically and radiographically examined before and one year after surgery. Clinical results were assessed using the British Orthopaedic Association (BOA) knee function chart (2).

The questions in the BOA chart on gait, the patient's own opinion, and the extension leg were excluded giving a maximal score of 39 points. The excluded variables were thoroughly assessed with other tests in this study.

One year after surgery the patients graded their opinion of treatment effects, using a six-grade scale (6 = very satisfied, 5 = marginally satisfied, 4 = somewhat satisfied, 3 = neither better nor worse, 2 = somewhat and 1 = very bad).

Radiographic examination included measurements of leg alignment, the Hip-knee-ankle (HKA) angle, from long X-ray films in the frontal plane of the whole leg at full weight bearing.

Prosthetic positioning and radiolucent zones around the components of the cement were determined from plain films in the frontal and the sagittal planes.

**Walking tests**

The walking tests described below were all performed during the same day, with a rest between the tests. The first series of tests was performed one day before surgery and the second series one year after surgery.

**Simple tests of walking ability**

Measurements of walking speed, pain and exertion during walking was used as simple tests of walking ability. The patients were asked to walk for four minutes in a corridor of 75 m, first at a self-selected, comfortable walking speed and after a rest, at their maximal walking speed. Walking speed was determined by a speedometer (in m·min⁻¹) (11). At the end of every walking test the patients were asked to grade their pain and exertion during walking using a ten graded scale (5).

**Advanced tests of walking ability**

Gait analysis. Gait analysis was performed on a force plate walkway consisting of two five meter long, force measuring platforms recording several consecutive steps from both feet during level walking (17).

The following parameters were measured:

- self-selected walking speed (m·min⁻¹)
- step frequency, F (steps/s)
- stride length/foot length, LFL (m)
- maximal vertical force, MVF (N) per kg body weight

The patients were instructed to walk with ordinary shoes first in their own familiar shoes walking speed and then three times in slower and three times in faster speeds. The mean of each parameter was based on altogether 12 gait runs, approximately 3·5 gait cycles. As these were performed over a range of walking speeds, it was assumed that a few gait runs would be performed in the same walking speed on the two occasions.

Walking efficiency. Energy cost of level walking was measured according to a previously described method by which oxygen cost and speed can be measured with high accuracy (11).

During the walking test the patients wore a lightweight bag (3.5 kg, volume 10 liters) on their back. They also wore a nose clip and breathed through a mouth piece connected to the mixing box by a flexible low-resistance hose. The gas mixture was subsequently analysed by means of a respiratory mass spectrometer (MDA 300, Concentrics, Craydon, UK). Ventilation and gas exchange were computed as described by Linnarsson et al. (11).

The oxygen cost was measured during walking at both self-selected and maximal walking speeds. One year after surgery, oxygen cost was also measured at the speed that was self-selected and comfortable preoperatively. To achieve this pre-determined walking speed the patients were guided by a test leader, who walked alongside pushing the speedometer (11).

**Statistical methods**

Student's t-test was used to test individual differences in the various parameters pre- and postoperatively and to test correlations. Pearson's or Spearman's correlation coefficient was used to identify the relationship between variables.

**RESULTS**

**Clinical assessment**

One year after surgery all knees were clinically stable. Leg alignment was corrected to an HKA angle less than 5 degrees of varus or valgus in all knees. Prosthetic positioning was considered satisfactory in all knees and one year after surgery there were no signs of prosthetic loosening.

The BOA score increased in all patients, as a mean from 30 points before surgery to 38 points after one year (Table 1). All patients stated significant pain relief after surgery.

One year after surgery most patients were very satisfied, four patients satisfied and one neither better nor worse. The patient, who did not experience improvement, had an injury nine months after surgery causing pain in the calf muscle during walking one year after surgery.

**Unicompartmental knee arthroplasty**

<table>
<thead>
<tr>
<th>Clinical scoring and simple tests of walking ability</th>
<th>Before surgery</th>
<th>One year after surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOA score (points)</td>
<td>30±4.2</td>
<td>38±1.1</td>
</tr>
<tr>
<td>Self-selected walking speed (m·min⁻¹)</td>
<td>62.5±8.3</td>
<td>74.2±5.9</td>
</tr>
<tr>
<td>Maximal walking speed (m·min⁻¹)</td>
<td>85.1±3.9</td>
<td>93.9±9.6</td>
</tr>
<tr>
<td>Pain (1–10) during walking at</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal speed</td>
<td>4.4±2.6</td>
<td>0.8±1.4</td>
</tr>
<tr>
<td>Speed = preoperative self-selected speed</td>
<td>3.3±2.3</td>
<td>0.4±0.9</td>
</tr>
<tr>
<td>Speed = postoperative self-selected speed</td>
<td>4.4±2.5</td>
<td>1.8±1.3</td>
</tr>
<tr>
<td>Speed = preoperative self-selected speed</td>
<td>3.0±2.2</td>
<td>0.9±1.3</td>
</tr>
</tbody>
</table>

*p < 0.001.

**Walking tests**

Twelve months postoperatively no patient used walking aids. Mean values for the different gait parameters are presented in Tables I, II and III.

**Simple tests of walking ability**

Self-selected walking speed was preoperatively 62.3 m·min⁻¹ and one year after surgery 42.0 m·min⁻¹. Seven patients had the same self-selected walking speed as normal subjects, 75 m·min⁻¹ (18), or even faster one year after surgery. There was a mean increase in self-selected walking speed of 11.8 m·min⁻¹ in 19 out of the 20 patients. The patient who had an injury, as described above, did not improve.

Maximal walking speed is presented in Table I. Two patients decreased their maximal walking speed. One of them, the patient who reported the injury, decreased 2.8 m·min⁻¹. The other patient decreased 4.1 m·min⁻¹ but he could already walk very fast preoperatively (109.2 m·min⁻¹).

One year after surgery all patients experienced decreased pain during walking at the speed that was self-selected preoperatively (p < 0.001) and 16 patients walked without any pain.

Pain during maximal speed walking was decreased in 19 patients (p < 0.001) and 12 patients walked without any pain.

One year after surgery all patients walked at the preoperative self-selected speed with decreased exertion (p < 0.001). At self-selected speed eighteen patients experienced decrease of exertion during walking (p < 0.001).

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**Advanced tests of walking ability**

Gait analysis. One year after surgery the patients had improved their average self-selected walking speed with 9.8 ± 7.0 m·min⁻¹ (p < 0.001). The ratio between the involved and uninvolved leg in single limb support and vertical force impulse had increased towards normal value (r = 0.5) (Table II). In all patients it was possible to find one gait run performed in the same walking speed on both occasions. When walking speed was thus treated as an independent variable, only duration of single limb support demonstrated a significant increase (Table III).

Walking efficiency. One year after surgery all patients increased walking speed p (0.001) during both self-selected and maximal walking speed. Oxygen cost of walking at self-selected walking speed was postoperatively decreased to the same level as that for normal subjects at the same speed.

**Relationship**

Clinical assessment. Individual improvement in BOA score was correlated with decrease of pain (r = 0.44, p < 0.05) and with decrease of exertion (r = 0.46, p < 0.05) during preoperative self-selected walking speed and with decrease of exertion (r = 0.49, p < 0.05) during maximal walking speed. There was no correlation between the individual improvement of the BOA score and the change of walking speeds, energy cost of walking or stride characteristics.
Table II. Gait analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before surgery</th>
<th>One year after surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single limb support (kph cycle)</td>
<td>0.94±0.05</td>
<td>0.99±0.04</td>
</tr>
<tr>
<td>Maximal vertical force (kph body weight)</td>
<td>0.98±0.02</td>
<td>0.96±0.05</td>
</tr>
<tr>
<td>Vertical force impulse</td>
<td>0.94±0.09</td>
<td>0.99±0.06</td>
</tr>
<tr>
<td>** p&lt;0.01; NS = no significance.**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The patients' opinion of treatment effects was not correlated with individual changes in measured parameters. However, correlations were found between rated own opinion and graded pain during walking at predetermined speed (r = -0.68, p<0.001) and maximal speed (r = -0.58, p<0.01) one year after surgery. Individual change of self-selected walking speed was correlated with individual change of maximal walking speed and change of single limb support (fully/unsupport) measured at different speeds pre- and postoperatively. Patients with the greatest increase of self-selected walking speed also had the greatest increase of maximal walking speed (r = 0.64, p<0.01).

Decrease of pain during walking at self-selected speed was correlated with decrease of pain during walking at maximal walking speed (r<0.77, p<0.001). Decrease of pain was also correlated with decrease of exertion during walking at the maximal speed (r = 0.55, p<0.01).

Individual decrease of oxygen cost of level walking was found to be correlated with decrease of pain (r = 0.42, p<0.05) and exertion (r = 0.45, p<0.05) determined at the same walking speed. There were no other correlations found between changes in oxygen cost and other measured parameters.

Individual changes in the parameters from the advanced gait analysis, measured at different speeds pre- and postoperatively, were only correlated with improvements in self-selected and maximal walking speed. Individual changes in the parameters from the advanced gait analysis, measured at the same speed, did not show any correlation with any other measured parameters.

Table III. Advanced tests of walking ability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before surgery</th>
<th>One year after surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step frequency (step/s⁻¹)</td>
<td>1.7±0.1</td>
<td>1.7±0.2</td>
</tr>
<tr>
<td>Single limb support (kph cycle)</td>
<td>1.4±0.2</td>
<td>1.4±0.2</td>
</tr>
<tr>
<td>Maximal vertical force (kph body weight, involved leg)</td>
<td>34.3±3.0</td>
<td>35.7±2.3</td>
</tr>
<tr>
<td>Oxygen cost of walking (mLkg⁻¹·m⁻¹)</td>
<td>105.7±7.6</td>
<td>105.1±4.8</td>
</tr>
<tr>
<td>Oxygen cost of walking (mLkg⁻¹·m⁻¹)</td>
<td>0.19±0.024</td>
<td>0.159±0.015</td>
</tr>
<tr>
<td>Oxygen cost of walking at maximal speed</td>
<td>0.195±0.022</td>
<td>0.165±0.017</td>
</tr>
</tbody>
</table>
| ** p<0.05, *** p<0.001, NS = no significance.**

DISCUSSION

In this study, walking capacity in patients with osteoarthrosis of the knee has been assessed before and one year after unicompartamental knee replacement. Only patients with symptoms from one knee with moderate medial osteoarthrosis were selected in order to constitute a uniform group of patients in whom the main obstacle for walking was knee pain.

After prosthetic replacement most patients are reported to be painfree and satisfied with the treatment. However, very little attention is usually paid to their walking capacity. One important aim of this study was to focus more interest on the functional outcome after knee replacement and to correlate such treatment evaluation to ordinary clinical scoring.

Advanced tests of walking such as gait analysis with measurements of stride characteristics and oxygen cost of walking provided objective values of walking capacity and reliable information of the surgical treatment effects. Some patients improved to test values which were equal to those of normal subjects (18). However, in our patients, in whom the main obstacle for walking was knee pain, simple walking tests such as measurements of comfortable and maximal walking speed were found to reflect satisfactorily walking ability and knee function.

One year after surgery all patients had improved in clinical scoring and in walking ability but the assessment of walking revealed that one patient who had sustained an injury to his calf muscles had not improved as much as the others.

Pain relief is an important goal in the treatment of patients with osteoarthrosis. The results from this study demonstrated that in spite of radiographically moderate signs of osteoarthrosis of the knee, patients experienced a lot of pain during walking. In comparison to results from a previous study, the average score for pain was higher than that for patients with severe osteoarthrosis of the hip (13). This difference might be explained by the fact that patients with osteoarthrosis of the hip can choose a more pain alleviating walking pattern. However, this chosen walking pattern has been found to require a higher oxygen cost of walking at corresponding walking speeds (12, 14, 20).

The results from this study showed that patients with moderate osteoarthrosis of the knee also have a changed walking pattern but not to the same extent as the patients with osteoarthrosis of the hip.

In some previous studies the maximal walking speed has been proposed as a useful parameter to assess treatment effects (12, 13). Patients with osteoarthrosis of the hip and knee joints are often elderly and are not accustomed to using their maximal walking speed and therefore the self-selected comfortable speed is more appropriate.

There was a high correlation between individual changes in maximal walking speed and self-selected walking speed; thus in our patients, any of these speeds could be used for assessment of treatment effects.

The self-selected walking speed in normal subjects has been shown to be the most efficient speed (18) but the patients in this study choose the walking speed that gave less pain.

CONCLUSION

For routine purpose clinical assessment, especially of pain, and measurement of self-selected walking speed have been found to properly reflect knee function in patients with moderate osteoarthrosis of the knee, but can be recommended as adequate parameters to assess treatment effects such as unicompartamental prosthetic knee replacement.

ACKNOWLEDGEMENT

This study was supported by grants from the Karolinska Institute research funds.

REFERENCES

The patients' opinion of treatment effects was not correlated with individual changes in measured parameters. However, correlations were found between rated own opinion and graded pain during walking at predetermined speed (r = -0.68, p < 0.001) and maximal speed (r = -0.58, p < 0.01) one year after surgery. Individual change of self-selected walking speed was correlated with individual change of maximal walking speed and change of single limb support (involved/uninvolved leg), measured at different speeds pre- and postoperatively. Patients with the greatest increase of self-selected walking speed also had the greatest increase of maximal walking speed (r = 0.64, p < 0.01).

Decrease of pain during walking at self-selected speed was correlated with decrease of pain during walking at maximal walking speed (r = 0.77, p < 0.001). Decrease of pain was also correlated with decrease of exertion during walking at the maximal speed (r = 0.55, p < 0.01).

Table III. Advanced tests of walking ability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Before surgery</th>
<th>One year after surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step frequency (steps s⁻¹)</td>
<td>1.7 ± 0.1</td>
<td>1.7 ± 0.2</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>1.4 ± 0.2</td>
<td>1.4 ± 0.2</td>
</tr>
<tr>
<td>Maximal vertical force (%)</td>
<td>34 ± 3.3</td>
<td>35.7 ± 2.3</td>
</tr>
<tr>
<td>Oxygen cost of walking (mL/kg/m)</td>
<td>105±7.6</td>
<td>105.1±4.8</td>
</tr>
<tr>
<td>Oxygen cost of walking at maximal speed</td>
<td>0.19±0.024</td>
<td>0.159±0.015</td>
</tr>
<tr>
<td>Oxygen cost of walking at self-selected speed</td>
<td>0.195±0.022</td>
<td>0.165±0.017</td>
</tr>
</tbody>
</table>

* p < 0.05, ** p < 0.001, NS = no significance.

The uncorrected gait speed has been proposed as a useful parameter to assess treatment effects (12, 13). Patients with osteoarthritis of the hip and knee joints are often elderly and are not accustomed to using their maximal walking speed and therefore the self-selected comfortable speed is more appropriate.

There was a high correlation between individual changes in maximal walking speed and self-selected walking speed; thus in our patients, any of these speeds could be used for assessment of treatment effects.

The self-selected walking speed in normal subjects has been shown to be the most efficient speed (18) but the patients in this study chose the walking speed that gave less pain.

CONCLUSION

For routine purpose clinical assessment, especially of pain, and measurement of self-selected walking speed have been found to properly reflect knee function in patients with moderate osteoarthritis of the knee, and can be recommended as adequate parameters to assess treatment effects such as unicompartamental prosthetic knee replacement.

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REFERENCES

THE INCREASE IN ENERGY COST OF WALKING WITH AN IMMobilIZED KNEE OR AN UNSTABLE ANKLE

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ABSTRACT. The effect of an immobilized knee joint or of an unstable ankle joint on the walking capacity has been assessed with 50 walking tests in ten healthy subjects. The knee joint was immobilized in extension with a standard splint and an unstable ankle joint was simulated by a modified shoe. A significant decrease in convenient walking speed was found. The energy cost of walking as assessed by oxygen cost at a convenient speed was significantly increased both with an immobilized knee (23%) and with an unstable ankle (10%), compared to the normal condition of the subjects. Implications for the management of patients with similar joint disorders are discussed.

Key words: efficiency, immobilization, instability, oxygen consumption, shoes, speed, splint.

The characteristics of normal gait have been extensively studied from a biomechanical point of view (4-10). Recent physiological studies of walking have shown that walking speed and energy cost are valuable parameters in the assessment of walking capacity both in normal subjects and in patients with walking disabilities (4, 5, 6, 11).

To our knowledge there is only one previous report on the effect of joint immobilization on walking efficiency (6). Based on a very small series without data on the walking speed, walking with immobilized knee or ankle joint was reported to increase oxygen uptake by 8 and 6%, respectively.

Oxygen cost during walking has also been studied in patients with neurologic diseases, in patients following total hip replacement and lower extremity amputations (1, 2, 3, 7, 9), but so far in patients with lower limb instability.

In an earlier publication (8) we have described a method of determining walking efficiency with great accuracy.

The aim of this study was to analyze to what extent immobilization of the knee or instability of the leg influences walking capacity by measuring walking speed and corresponding energy cost.

SUBJECTS AND METHODS

Ten subjects, 3 men and 7 women, volunteered to participate in this study. None of them suffered from heart or lung disease and none had any musculoskeletal symptoms. The mean age of the subjects was 39.5 ± 7 years (mean ± SD), mean weight 62.5 ± 10.5 kilograms and mean height 172 ± 9 centimetres.

The walking test

Five different walking tests were performed on each subject on each occasion. The subjects walked along a 30 meter long corridor. The heart rate was registered with a pulsmeter (Sprint Tester TM 9500). To ensure physiological steady state conditions the subjects walked for a minimum of 4 min, with an unchanged heart rate during the latter part.

Walking speed was determined by a speedometer mounted on a small cart, which was pushed alongside the patient. Mean walking speed was also calculated as the ratio between distance and time. The subjects were asked to select the walking speed that was most convenient.

In the first walking test, used as a reference test, the subjects wore a pair of normal Swedish clogs. In the second walking test the right shoe was exchanged to a similar wooden clog but with a convex sole making the foot as well as the leg unstable. In the third walking test the subjects walked with normal Swedish clogs but with the right knee immobilized in extension in a splint.

The fourth and fifth walking tests were performed with the normal wooden clogs at the speeds which were determined in previous tests with unstable leg and immobilized knee. To achieve those predetermined walking speeds the subjects were guided by a tester who walked alongside, pushing the speedometer cart.

Energy cost

During the walking tests the subjects wore a tight-light weight box (2.5 kilograms, volume 10 liters) on their back. They also wore a nose clip and breathed through a mouth piece, connected to the mixing box by a flexible low-resistance hose. Argon gas with a constant well-defined flow was added at the inlet of the box for determination of ventilation. A sample of the gas mixture, contained in the box at the end of the walking test, was aspirated with a glass-syringe and was subsequently analyzed by a respiratory mass spectrometer (Cottontools MGA 200). Ventilation and gas exchange were calculated as earlier described (8). Collection of expired gas and determination of oxygen cost was performed after each test.

References


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