Quantity versus quality of gait and quality of life in patients with osteoarthritis

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Abstract

Purpose: This study investigated the relationship between the quality of life, quality of gait and the quantity of gait in patients with impairments in the lower extremities.

Methods: Twenty-six subjects (age 58.6 ± 13.4 years) suffering from knee or hip osteoarthritis were investigated before implantation of an endoprosthesis. Quality of life was assessed using the SF-36 survey. The quality of gait was assessed with a six camera motion analysis system in combination with two force plates. For evaluation of the quantity of gait, two monitors were applied: (a) the accelerometer-based DynaPort activity monitor measured locomotion and posture for 1 day and (b) The Step-Activity-Monitor, a small microprocessor-operated acceleration sensor, measured the number of gait cycles in 1-min intervals for 1 week. Spearman correlation coefficients were calculated between quantity of gait, quality of gait and quality of life.

Results: The patients showed typical gait impairments caused by osteoarthritis. Locomotion accounted for 10.5 ± 5% of the daily recorded time, 4782 ± 2116 gait cycles were counted per day. The sub-categories of the SF-36 showed limited physical functioning and general health with 38 and 56 out of 100 points, respectively. Computation of Spearman-rho revealed no relevant correlations between quality and quantity of gait, but moderate correlations between quality of life and quantity of gait.

Conclusion: The findings underline that a patient’s level of mobility cannot be reliably estimated from quality of gait or from quality of life. Instead, adequate methods should be chosen to measure the quantity of gait in daily life.

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1. Introduction

Gait analysis under controlled laboratory conditions has become a useful and widely accepted tool for clinical use and research purposes [1,2]. The results of clinical gait analysis usually identify underlying causes of gait abnormalities and therefore, support the decision making process [1]. Thus, clinicians are not solely dependent on visual inspection of the subject’s gait [3]. Furthermore, clinical gait analysis is used to evaluate treatment outcome [4–6]. Additional measurement techniques such as electromyography or specific test conditions aiming to reflect daily life situations (e.g. the knee test [7]), offer further information. However, it is unclear if walking under laboratory controlled conditions is representative of natural walking performance [8] or sufficient to reflect patients’ mobility in daily life. Therefore, clinical gait analysis may not reveal functional subject variability in everyday activity patterns [1]. Clinical gait analysis demonstrates the walking ability of a subject at a selected point in time and a particular setting [9]. Assuming that a patient would present his/her best possible walking in the gait lab, the findings represent “how well” the subject is able to walk and reflect the quality of his/her gait. It remains unclear to what extent subjects use their maximum potential in walking during daily life.

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Recently, new technologies were developed to measure quantitative gait parameters in daily living, using accelerometry [10,11] or step counting methods [12,13]. These methods allow for an objective quantification of everyday activities and were used for assessing mobility in specific patient populations with orthopaedic [14], neurological [13] or pulmonary [15] impairments. Furthermore, the ability to independently ambulate indoors and outdoors is important in determining quality of life, from both the patients’ and the therapists’ point of view [16]. Objective measurements of physical activity level are, therefore, clinically desirable.

The comparison between gait in the laboratory environment and in daily living has not been studied sufficiently. In 2002, Kennedy et al. [17] assessed the relationship between objective functional measures and a self-reported, subjective measure of preoperative function in 761 hip and 1044 knee arthroplasty candidates. The results revealed a greater disability in women than in men but in general, there was only a low to moderate correlation between functional measures and self-reports ($r = 0.21–0.50$). However, it is unclear to what extent objectively measured quantitative gait parameters are correlated with objectively assessed qualitative parameters or subjective parameters of life quality. Therefore, we compared quality and quantity parameters of gait in subjects with impairments of the lower extremities.

We studied patients with hip or knee osteoarthritis, the most common reason for walking impairment [18,19] known to be associated with a significant loss in functional performance and high social costs [20].

### 2. Methods

Twenty-six patients suffering from primary unilateral hip or knee osteoarthritis and already scheduled for joint replacement surgery were recruited from relevant clinics following informed consent. The study was approved by the local Ethics Committee. Anthropometric data and distribution of knee and hip patients are provided in Table 1. Clinical gait analysis, ADL-monitoring and the SF-36 questionnaire were undertaken pre-operatively.

#### 2.1. Gait analysis

The gait analysis included five complete gait cycles of each foot in full gait. A six camera Motion Analysis system (Motion Analysis Corp., Santa Rosa, CA, USA) collected data at 60 Hz using the Helen Hayes marker-set for determining the subjects’ gait kinematics. Two AMTI force plates (AMTI, Watertown, MA, USA) in the walkway measured ground reaction forces (GRF) at 600 Hz. Standard software (Eva 5.2 and Ortho-Trak 4.1, Motion Analysis Corp.) was used for data processing and synchronisation of kinematics and kinetics. Finally, the relevant parameters were exported by a Microsoft Excel 2002 macro (Table 2).

#### 2.2. SF-36

Subsequent to the gait analysis, the subjects filled out the SF-36 questionnaire assessing subjects’ general health perceptions. The outcome was calculated as a subdivision in the categories physical functioning, physical role, pain, general health, vitality, social functioning, emotional role and mental wellbeing.

#### 2.3. Physical activity assessment

For the measurement of the quantity of gait, the subjects were visited at home on the next day early in the morning to ensure sufficient measurement duration on the same day. Two devices were applied to quantify the activities of daily living of the subjects. The DynaPort ADL-monitor (McRoberts BV, The Hague, The Netherlands) consists of three acceleration sensors, a recording unit and an external battery supply. It measures precisely the time spent in different activity categories such as locomotion (walking, bicycling), standing, sitting and lying as well as movement intensity [21]. Technical specifications have been presented previously [22]. The ADL-monitor was applied for 1 day collecting activities from early in the morning until bedtime in the evening. On the next day, the primary investigator retrieved the ADL-monitor.

The Step Activity Monitor 3.0 (SAM, Cyma Corp., WA, USA) is a completely sealed uniaxial acceleration sensor with a size of 75 mm × 55 mm × 20 mm and a weight about 40 g. The SAM is mounted on the right ankle and measures the number of gait cycles taken by the subject. The accuracy of the device has been reported to be above 98% when adjusting its sensitivity and cadence to the subject’s individual gait characteristics [23,24]. Depending on the sampling interval and activity level of the subject, the SAM can measure and store data for several weeks in 1-min intervals. Data is downloaded using a docking station and is processed with dedicated software (StepWatch 3.1, Cyma Corp.). Subsequently, the data is exported to Microsoft Excel for computation of intensity levels in steps of 10 gait cycles per minute:

- **a. Absolute intensity:** absolute number of recorded minutes with 1–10, 11–20, 21–30, 31–40, 41–50 and above 50 gait cycles per minute.
- **b. Relative intensity:** the percentage of the number of recorded minutes with 1–10, 11–20, 21–30, 31–40, 41–50 and above 50 gait cycles per minute compared to the number of all minutes with detected gait cycles.

Intensities from 1 to 20 gait cycles can be regarded as low intensity reflecting intermittent short-term activity, for example, moving within a room. Twenty-one to forty gait cycles per minute can be interpreted as moderate intensity expressing mid-term activity, for example, moving from one room to another. More than 40 gait cycles per minute can be seen as high intensity such as systematic and continuous activity, for example, moving outdoors.

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**Table 1**

Antropometric data of participants

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Female ($n$ = 17)</th>
<th>Male ($n$ = 9)</th>
<th>Total ($n$ = 26)</th>
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<tr>
<td>Age (years)</td>
<td>62.5 ± 12.3</td>
<td>51.1 ± 12.7</td>
<td>58.6 ± 13.4</td>
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<tr>
<td>Height (cm)</td>
<td>163.6 ± 73.8</td>
<td>183.8 ± 9.5</td>
<td>170.6 ± 12.1</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.8 ± 11.0</td>
<td>92.2 ± 10.1</td>
<td>80.2 ± 13.8</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.6 ± 4.4</td>
<td>27.4 ± 3.2</td>
<td>27.6 ± 3.9</td>
</tr>
</tbody>
</table>

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**References**

[10][11][12][13][14][15][16][17][18][19][20][21][22][23][24]
The SAM was applied on the first day simultaneously with the ADL-monitor by the primary investigator. The patients were instructed to wear the SAM for 7 consecutive days and mail the device back to the Motion Analysis Laboratory. The patients were asked to attach the SAM after getting up in the morning, to detach it when going to bed in the evening and to record the times of attachment and detachment as well as the time of measurement interruptions due to incompatibility with wet conditions (e.g., swimming, bathing).

2.4. Data processing

Spearman rank-correlations between gait parameters (gait analysis), percentage of activities (ADL-monitor), movement intensity (ADL-monitor), number of steps (SAM) and SF-36 categories were computed using SPSS 11.0.1 for Windows. The step activity data of the patients was compared to step activity data from 26 healthy subjects (aged 44.6 ± 9.6 years) taken from the data base of the Motion Analysis Laboratory.

3. Results

In one subject, the gait analysis could not be carried out because the subject’s step length was too short for single foot contact on the force plates. A short overview of gait quality for the remaining 25 subjects is given in Table 3. Subjective health perceptions of the patients are provided in Table 4.

Complete data sets of the ADL-monitor with an average recording time of 13.8 ± 1.5 h were obtained from 17 patients. This total time was identified and automatically categorized as locomotion in 10.5 ± 5%, standing in 32.6 ± 12.3%, sitting in 43.9 ± 15.1% and lying in 12.5 ± 11.1% (Fig. 1). Only 0.4% of the signals could not be classified. The average movement intensity during locomotion was 2.0 ± 0.5 m/s². Reasons for incomplete data sets included technical problems (n = 2) and measurement duration of less than 10 h (n = 2). This was considered to represent the measured day inadequately. On two occasions, no ADL-monitor was available and two subjects did not comply with the application of the ADL-monitor. For all 26 subjects, the assessment of the number of gait cycles was successful. On average, the SAM was worn for 14.0 ± 1.4 h. The results of the patients in comparison with the healthy adults are given in Table 5.

A significant correlation was found between the percentage of locomotion (ADL-monitor) and the step width (r = 0.6, p < 0.02), whereas no relevant correlation existed between the number of gait cycles (SAM) and the gait parameters. Relevant correlations between the SF-36 score, the quality and the quantity of gait were found between physical functioning and gait velocity (r = 0.7, p < 0.01), physical functioning and percentage of standing (r = −0.5, p = 0.04), percentage of locomotion and number of gait cycles (r = 0.6, p = 0.02).

A computation of correlations between SF-36 categories and gait cycles expressed in absolute and relative intensity revealed several significant correlations. Patients with better values in physical functioning showed a higher percentage of gait cycles at a higher intensity (31–40, 41–50 gait cycles per minute, r = 0.6, p = 0.02). Patients with better values in pain demonstrated higher absolute and relative intensities (31–40 and 41–50 gait cycles per minute, r = 0.6–0.7, p < 0.03). This phenomenon was also observed between the general health perceptions (SF-36) and high absolute and high relative intensities (31–40 and 41–50 gait cycles per minute, r = 0.5–0.6, p < 0.01). The correlations between vitality, social functioning, emotional role and the relative intensity of 31–40 and 41–50 gait cycles per minute were in the range of r = 0.5–0.6, p < 0.03.

The difference between the patients and healthy adults was significant for the absolute number of gait cycles with more than 21 gait cycles per minute (Table 5) indicating that...
the healthy subjects performed a significantly higher number of gait cycles with a frequency of more than 21 gait cycles per minute compared to the investigated patients. Furthermore, the difference between the patients and the healthy adults was significant for the relative number of gait cycles with more than 31 gait cycles per minute, indicating that the distribution of the walking frequencies of the healthy subjects is shifted towards higher frequencies as compared to the patients.

4. Discussion

The study was carried out with a primary focus on the relationship between quality and quantity of gait, thus clinical findings are not discussed in detail. Quality of gait, as reflected by kinetics and kinematics, was in accordance with previously described deviations from normal values [5,25]. These can be summarized as protection mechanisms, as suggested by Rompen et al. [6].

Patients scheduled for knee replacement showed a higher level of locomotion and movement intensity compared to COPD patients [21] and amputees [26] and similar duration of locomotion compared to healthy adults [21,22]. However, they displayed lower movement intensities [21]. Our patients spent more time for locomotion before surgery but less time compared to a group of knee patients 6 months after surgery reported from a different region in Germany [27].

The number of gait cycles performed by healthy subjects measured by the Motion Analysis Laboratory was similar to mean values previously reported for healthy adults of similar age [13]. The difference between the healthy subjects and the knee patients underlines the impact of the disease on mobility parameters. Actually, patients with well-functioning hip prostheses performed more gait cycles post-operatively (~5200 gait cycles/day) [14]; the same holds true for the previously mentioned knee patients 6 months after surgery [27]. Since patients showed similar standard deviation but a lower mean in their daily gait cycles compared to the healthy subjects, patients’ physical activity appears to be more variable. The statistical analysis suggests that the discrepancy to healthy adults is mainly caused by the differences in moderate and high intensities (Table 5).

The results from the ADL-monitor and the step activity monitor indicate that knee patients and healthy adults are physically active for a similar duration per day, but patients are not able to perform the same amount of activity during locomotion time (Table 5). Consequently, knee arthrosis limits the ability to perform moderate and high activities.

The poor correlations between the quantitative assessment of the gait cycles during daily life and the qualitative analysis of gait under laboratory settings imply that the two measurements are not linked. The correlation between the percentage of locomotion, assessed by the ADL-monitor, and the patients’ step width is not clinically relevant, because the information about the quality of gait from step width is controversial. On one hand, a shorter step width may indicate an improved balance [28] and discriminate between...
young and elderly subjects with respect to body control [29,30]. On the other hand, it was reported that an increased step width does not necessarily improve stability [31]. Furthermore, Moe-Nilssen and Helbostad recommended against the use of step width as a criterion for the distinction between frail and fit elderly adults [32].

In summary, none of the included parameters of the clinical gait analysis was suited to estimate the quantity of locomotion of the patients. Consequently, results from clinical gait analysis, representing the subject’s best walking ability, cannot be used to predict the level of activity in daily life. The SF-36 seems to be sufficiently sensitive to characterize patients who remain more or less active in spite of their disease. Similar to the findings between healthy adults and patients, a better subjective physical function is reflected in the performance of higher intensities during walking. Interestingly, other SF-36 categories which are not focused on physical functioning are also related to the degree of high intensities during walking. This underlines that osteoarthritis limits the patients’ ability to ambulate with higher intensities and, consequently, that the reduction of this capability may influence on social and mental aspects. However, taking into account the moderate correlation between SF-36 and objectively measured physical activity, an estimation of the amount of physical activity based on the results of the SF-36 can lead to inaccurate values. Furthermore, the reliability of questionnaires is still a matter of debate.

In conclusion, the quality and quantity of gait and the subjective quality of life are not inter-related and should be studied separately using appropriate independent, objective and reliable methods. The methods used in this study explored different aspects of the clinical conditions studied and were not necessarily related to each other. For the assessment of mobility improvement as a treatment goal, a sole application of gait analysis and SF-36 may not sufficiently reflect the individual outcome.

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Conflict of interest

The Motion Analysis Laboratory at the University of Munster and Department of Trauma and Reconstructive Surgery, Raphael’s Hospital, Muenster, Germany, have no commercial interest and/or benefit of the attached publication. There are no professional relationships with the manufacturers/companies of the utilized devices.

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References


