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Influence of surgical treatment of selected malignant tumours on gait kinematics – a pilot study

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Anna Latajka[1], Marek Woźniewski[2], Iwona Malicka[2]

[1] Lower Silesian Oncology Centre in Wroclaw, Wroclaw, Poland

[2] Faculty of Physiotherapy, University School of Physical Education in Wroclaw, Wroclaw, Poland

Abstract

Introduction. Assessment of the influence of surgical treatment of selected malignant tumours on gait kinematics.

Methods. The study involved 115 patients of the Lower Silesian Oncology Centre in Wroclaw, Poland (95 women and 20 men), mean age 58.39 ± 11.14 years, treated surgically for diagnosed cancer (group A: breast cancer; group B: reproductive cancer; group C: gastrointestinal cancer). Gait measurements were performed with the BTS G-Walk accelerometer before and after the surgery (5th–6th postoperative day). The *t*-test for dependent samples and analysis of variance – least significant difference test – were applied.

Results. A significant decrease in cadence and walking speed was observed, by 7.9% ($p < 0.001$) and 17.5% ($p < 0.001$) in group B, and by 4.0% ($p < 0.001$) and 11.7% ($p < 0.001$) in group C, respectively. Additionally, there was an upward trend for symmetry of pelvic tilt in the sagittal plane (67.9% vs. 76.7%, $p = 0.09$) in group A, and a significant difference in pelvic deflections in the frontal plane (94.8% vs. 88.1%, $p = 0.02$) in group C. Statistically significant differences were found in walking cadence between groups A and B ($p = 0.002$), and in walking speed between group A and groups B and C (group A vs. B: $p < 0.001$; group A vs. C: $p = 0.03$).

Conclusions. In patients treated surgically for reproductive system and gastrointestinal cancers, a decrease in time and space parameters of gait was demonstrated. Additionally, in patients treated for gastrointestinal cancers, the effect of surgical treatment on gait kinematics was found.

Key words: cancer, surgical treatment, gait kinematics, gait cadence, gait disorders

Introduction

In Poland, as well as worldwide, cancer is a serious health problem [1]. It is recognized to be a severe chronic disease [2], and the risk of getting cancer increases with age – ca. 60% of cancers in women and ca. 70% of cancers in men develop after the age of 60 [3]. In Poland, life expectancy is currently 75.8 years; it is expected that in the coming years, the general structure of the Polish society will include 18.2% of elderly people [3]. The problem of cancer largely affects older people, in whom the need to ensure mobility becomes very important, both for social and ethical reasons.

Surgery is the oldest and one of the most effective means of treating cancer. Most surgical operations, however, are characterized by the extent related to the need to remove the tumour together with a margin of healthy tissue, as well as with surrounding lymph vessels and nodes. Thus, they lead to complications and functional disorders [4].

The most common malignant tumour in women is breast cancer. Damage to anatomical structures during surgery may contribute to upper body quadrant dysfunctions [5, 6]. Disturbances of chest wall muscle balance and the resulting disorders of postural muscle balance may lead to postural defects – deepening of thoracic kyphosis and lumbar lordosis, which may in turn contribute to the occurrence of low back pain [7]. Low back pain is often accompanied by changes in gait; during walking, trunk muscles that support stability, rotation, and lifting of the pelvis and its movements in the sagittal plane are activated. Decreased walking velocity and pelvis rotation asymmetry may occur [8, 9].

High incidence among women is also observed for reproductive cancers (endometrial, cervical, and ovarian cancers). Surgical treatment in the lower abdomen may contribute to restricted hip mobility and flexion contracture [10]. Hip flexion contracture causes increased pelvic anteversion during the support phase and, together with pain after surgery, can result in crouch gait. Additionally, a reduced range of hip movement is also associated with reduced walking speed [11].

Gastrointestinal cancers, in particular colorectal cancer, are also a serious epidemiological problem nowadays. Abdominal surgery is associated with damage and weakness of abdominal muscles, which may lead to deepening of lumbar lordosis, and may be a factor causing lower back pain [12]. The patient usually leans forward, adopting a hunched posture, and the walk becomes cautious, usually with small steps. Thoracic and pelvic movements are reduced. As a consequence, gait disturbances may occur, in terms of both spatiotemporal and kinematic parameters [8].

Gait is a natural human need. The possibility of independent and proper free movement is a priority in daily functioning of patients with malignant tumours. Many musculoskeletal system and nervous system diseases cause an abnormal gait pattern or completely prevent walking. The reasons for the occurrence of a pathological gait pattern may be limitation of joint mobility, deformities, injuries, decreased muscle strength, neuromuscular disorders, and pain. A disturbed gait pattern

Correspondence address: Anna Latajka, Dolnośląskie Centrum Onkologii, pl. Hirszfelda 12, 53-413 Wrocław, Poland, e-mail: latajka.anna@dco.com.pl

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may not only limit the efficiency of walking and cause increase in energy expenditure, but also result in secondary, incorrect compensatory reactions that can be fixed [13, 14]. Therefore, it is important to take appropriate measures to detect possible functional disorders, which in turn contribute to a greater risk of falls [6], particularly in elderly people [15]. Gait is considered to be one of the most reliable parameters reflecting the patient's overall condition and a factor predicting safe movement in daily life [15]. Studenski et al. [16] suggest further that gait speed along with variables such as sex and age may determine the goals of medical care for older people.

Literature review showed a small number of publications on gait analysis in patients treated for cancers [17–19]. The available studies concern mainly patients after hip or knee arthroplasty and those suffering from Parkinson's disease, reporting primarily changes in the spatiotemporal and kinematic parameters of gait [20–25].

Gait analysis with the use of devices with gyroscopic mechanisms that analyse gait, along with simultaneous measurement of gait speed, loading time of individual limbs, and three-plane pelvic tilts, has been available so far only under the conditions of complex machinery and space restrictions, e.g. in specialized laboratories. Technological progress, and thus minimization of devices and the use of sensitive GPS receivers, allow currently to carry out the analyses in natural settings and under conditions often not available so far, including hospital environment.

In connection with the above, the aim of this study was to assess the influence of surgical treatment of selected malignant tumours on gait kinematics.

Subjects and methods

Study group

The study group comprised 115 patients of the Lower Silesian Oncology Centre in Wroclaw, Poland (95 women and 20 men) of the mean age of 58.39 ± 11.14 years, treated surgically for diagnosed cancer. The mean body height was 164.20 ± 7.48 cm, mean body weight 74.29 ± 15.69 kg and mean BMI 27.49 ± 5.23 kg/m^2.

The patients were divided in a targeted manner into 3 groups, depending on the area of the surgery performed:

– Group A (*n* = 37, women): patients treated surgically for breast cancer – chest surgery (mastectomy, mastectomy with simultaneous implant-based reconstruction, quadrantectomy with lymphadenectomy).

– Group B (*n* = 44, women): patients treated surgically for reproductive cancer (endometrial cancer, ovarian cancer, cervical cancer) – surgery in the area of lesser pelvis (gynaecologic oncology procedures with an open incision in the abdomen – abdominal surgery).

– Group C (*n* = 34; 14 women, 20 men): patients treated surgically for gastrointestinal cancer (gastric cancer, colorectal cancer, rectal cancer) – extensive surgeries involving long abdominal incisions (oncological laparotomies).

Detailed characteristics of the studied groups are presented in Table 1.

Methods

Each patient was tested twice: before the surgery and on the day of discharge from hospital (5–6 days after surgery). In all patients, gait measurements on the distance of 20 m were performed with the BTS G-Walk accelerometer.

The G-Walk is a wireless system consisting of an inertial sensor composed by a triaxial accelerometer, a magnetic sensor, and a triaxial gyroscope.

A sensor (BTS G-Walk, sensor) was placed on the patient's body with a belt at the level of lumbar spine (in the area of the L4-L5 intervertebral space), and the patient's task was to walk 10 m in one direction at their own speed, then to turn around and walk 10 m back. During both tests, the patient had the same footwear.

The collected data were then sent via Bluetooth to a computer and processed with the dedicated BTS G-Walk software. BTS G-Walk accelerometer is a system with many applications, dedicated to diagnosis and research [26]. The device acquires accurate and objective (non-normalized and normalized) kinematic data during the walk. On the basis of literature reports concerning BTS G-Walk [26–32], the following spatiotemporal gait parameters were evaluated:

– walking cadence (steps/min) – number of steps per minute;

– walking speed (m/s) – the average instantaneous speed within the gait cycle;

– symmetry index (%) – which quantifies how much the profile of the right curve is similar to the profile of the left curve; ideally, if the two curves are perfectly overlapping, the index is 100 and it means that the two curves have the same value frame by frame;

– symmetry of pelvis position in 3 planes:

a) pelvic tilt index (%) – symmetry of pelvic tilt in the sagittal plane,

b) pelvic obliquity index (%) – symmetry of pelvic obliquity in the coronal plane,

c) pelvic rotation index (%) – symmetry of pelvic rotation in the transverse plane.

For the pelvic tilt, values higher than 40 can be considered as normal ones. For the pelvic obliquity and rotation angles, the normal value is 80–100 (according to the guidelines of the manufacturer, BTS Bioengineering, Milan, Italy).

The BTS G-Walk device uses the mathematical function of correlation applied to the two curves:

$$\text{Symmetric index} = (\text{corr} + 1) \times 100/2$$

where: corr is the Pearson correlation coefficient between the mean left and right normalized anteroposterior acceleration signal (according to the manufacturer's guidelines).

Table 1. Statistical characteristics of age and somatic parameters of the studied groups (means + *SD*)

Feature	Total (*n* = 115)	Group A (*n* = 37)	Group B (*n* = 44)	Group C (*n* = 34)
Age (years)	58.39 ± 11.14	57.57 ± 12.16	55.77 ± 10.26	62.68 ± 10.07
Body weight (kg)	74.29 ± 15.69	76.78 ± 18.48	73.43 ± 16.14	72.68 ± 11.29
Body height (cm)	164.20 ± 7.48	163.32 ± 6.92	162.64 ± 5.39	167.18 ± 9.49
BMI (kg/m^2)	27.49 ± 5.23	28.62 ± 5.68	27.72 ± 5.81	25.97 ± 3.39

Statistical analysis

Statistical calculations were performed with the use of the Statistica software. Means and standard deviations were determined. The normality of distribution was verified with Shapiro-Wilk test, and the homogeneity of variance with Levene's test. The *t*-test was performed (intragroup analysis), and additionally, analysis of variance – with *post-hoc* testing – with the least significant difference test for comparison of differences dependent on surgery (intergroup analysis) was conducted. The level of statistical significance for the relationships under investigation was set at $p < 0.05$.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Local Bioethics Committee at the University of Physical Education in Wroclaw, Poland (consent No. 28/2018).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

In the study group, there was observed a decrease in walking cadence by 4.6% compared with the first measurement, and a decrease in walking speed by 11.7% (Table 2).

For the group of patients after breast cancer surgery (group A), the decreases in walking cadence and speed were not statistically significant. In the groups of patients treated surgically for reproductive cancer (group B) and gastrointestinal cancer (group C), statistically significant differences were found, in terms of both gait cadence and speed. The gait cadence for group B in the second test decreased by 7.9% in relation to the mean of the first measurement, and the speed decreased by 17.5% compared with the pre-surgery mean. In group C, gait cadence decreased by 4.0% and walking speed decreased by 11.7%. Detailed data are presented in Table 2.

The gait symmetry index did not show statistically significant differences either for all the studied patients or in the particular groups.

In the study group, the change in pelvis motion symmetry between the two measurements (preoperative test vs. postoperative test) was statistically significant for the coronal plane (94.2% vs. 89.7%, $p = 0.03$). There were no significant differences for the movement of pelvis in the sagittal or transverse planes (Table 3).

Table 2. Gait cadence and walking speed in the studied groups

	Preoperative test (mean ± *SD*)	Postoperative test (mean ± *SD*)	*p*
Gait cadence (*n* = 115) (steps/min)	112.47 ± 11.95	107.24 ± 12.89	< 0.001*
Group A (*n* = 37)	114.53 ± 12.17	112.90 ± 10.06	0.34
Group B (*n* = 44)	116.06 ± 7.48	106.91 ± 12.05	< 0.001*
Group C (*n* = 34)	105.75 ± 14.22	101.52 ± 14.87	< 0.001*
Walking speed (*n* = 115) (m/s)	1.11 ± 0.18	0.98 ± 0.20	< 0.001*
Group A (*n* = 37)	1.08 ± 0.21	1.04 ± 0.22	0.10
Group B (*n* = 44)	1.14 ± 0.15	0.94 ± 0.18	< 0.001*
Group C (*n* = 34)	1.11 ± 0.19	0.98 ± 0.21	< 0.001*

* statistically significant results

Table 3. Symmetry of pelvic motion in the studied groups

	Preoperative test (mean ± *SD*)	Postoperative test (mean ± *SD*)	*p*
Pelvic tilt index (*n* = 115) (%)	65.92 ± 23.96	69.85 ± 23.13	0.13
Group A (*n* = 37)	67.93 ± 27.87	76.71 ± 18.58	0.09
Group B (*n* = 44)	69.12 ± 19.85	71.70 ± 21.98	0.52
Group C (*n* = 34)	59.74 ± 24.96	60.12 ± 27.24	0.93
Pelvic obliquity index (*n* = 115) (%)	94.21 ± 13.57	89.73 ± 19.54	0.03*
Group A (*n* = 37)	97.20 ± 5.31	91.91 ± 19.17	0.11
Group B (*n* = 44)	91.11 ± 20.66	89.10 ± 21.25	0.46
Group C (*n* = 34)	94.85 ± 7.51	88.15 ± 19.16	0.02*
Pelvic rotation index (*n* = 115) (%)	86.05 ± 21.90	83.40 ± 24.92	0.35
Group A (*n* = 37)	89.46 ± 15.14	82.17 ± 29.28	0.20
Group B (*n* = 44)	85.98 ± 25.17	84.77 ± 23.74	0.81
Group C (*n* = 34)	82.43 ± 24.80	83.03 ± 23.29	0.89

* statistically significant results

Table 4. Significance of differences between groups for gait cadence

	Gait cadence (steps/min): differences between preoperative test and postoperative test (*p* values)		
	Group A (mean = 1.63)	Group B (mean = 9.15)	Group C (mean = 4.22)
Group A		0.002*	0.31
Group B	0.002*		0.05
Group C	0.31	0.05	

***** statistically significant results

Table 5. Significance of differences between groups for walking speed

	Walking speed (m/s): differences between preoperative test and postoperative test (*p* values)		
	Group A (mean = 0.04)	Group B (mean = 0.19)	Group C (mean = 0.12)
Group A		< 0.001*	0.03*
Group B	< 0.001*		0.10
Group C	0.03*	0.10	

* statistically significant results

Considering the particular groups, in the group of women treated surgically for breast cancer, an upward trend was found for the symmetry of pelvic tilt in the sagittal plane (67.9% vs. 76.7%, $p = 0.09$), whereas no significant differences were observed in the other groups. Symmetry of pelvic motion in the coronal plane was significantly different in the group of patients treated surgically for gastrointestinal cancer (94.8% vs. 88.1%, $p = 0.02$), while no significant differences were noted for the symmetry of pelvic rotation in the transverse plane (Table 3).

For each group, the range of changes of the above parameters between the tests was also calculated, with the first measurement assumed as the patient's standard. The differences between the groups were significant for gait cadence (group A vs. B; Table 4) and for walking speed (group A vs. groups B and C; Table 5), while no significant differences were found for the gait symmetry index and pelvic position, irrespective of the tested plane.

Discussion

Walking is a complex activity connected with efficient functioning of several, e.g. musculoskeletal, cardiovascular, pulmonary, and neurological systems [33]. Cancer and its treatment may contribute to psychophysical disorders and changes in the above systems, leading to limitation of physical activity and a decrease in the quality of life.

This study showed a significant decrease in gait cadence and walking speed of patients treated surgically for reproductive and gastrointestinal cancer. The decrease of gait cadence in the group of women treated for reproductive cancer was 9.15 steps/min, and the decrease of walking speed was 0.19 m/s. In patients diagnosed with gastrointestinal cancer the values were 4.22 steps/min and 0.13 m/s, correspondingly. Walking speed is considered to be the most important gait parameter.

The results obtained by Perera et al. [34] suggest that a change in walking speed by 0.05 m/s is small but clinically meaningful, while that exceeding 0.10 m/s is significant for mobility. Therefore, it can be concluded that surgical treatment of the aforementioned cancers caused a significant change in the mobility of the treated persons.

Walking speed is also considered a predictive fall risk factor. Quach et al. [35] and Van Kan et al. [36] showed that the lowest risk of falls occurs at the walking speed of 1–1.3 m/s. Quach et al. [35] stated that both lower (< 0.6 m/s) and higher (> 1.3 m/s) walking speeds significantly increase that risk. Van Kan et al. [36], in turn, determined the limit value of walking speed to be 1.0 m/s, not only recognizing it as significant in regard to a greater risk of falls, but also considering it to be a predictor of hospitalization and mortality. The presented study showed mean values of walking speed in the second test equal 0.94 m/s and 0.98 m/s for patients treated for reproductive cancer and for those treated for gastrointestinal cancer, respectively. Those groups were significantly different in the intergroup comparison with the patients treated surgically for breast cancer. Significant differences both in gait cadence and in walking speed were found in the group of women treated surgically for reproductive cancer; patients operated for gastrointestinal cancer were characterized with significant differences in walking speed.

In view of the above, it is important to implement appropriate physiotherapeutic measures that will allow patients to remain independent in basic activities of their daily living and to quickly return to an active social life.

Additionally, changes in the symmetry of pelvic position were observed in this study. A significant change was noted for coronal plane in patients treated surgically for gastrointestinal cancer. Pelvic motion within the coronal plane is a direct factor of minimizing vertical displacement of the body centre of mass [37]. In the case of patients treated for gastrointestinal cancer, antalgic posture and gait may have occurred (thoracic kyphosis with flexion of the hips and knees), which translated into a change in gait. Even a slight restriction of hip range of motion may disturb the normal gait pattern. Hip extension is required at the end of the stance phase. If the trail limb is not straightened in the hip joint during the terminal stance phase, the efficiency of swing decreases. Hip joint range of motion restriction therefore forces shortening of stride length, which in turn requires reduction of the range of extension movement at the hip joint [38]. This change may have an impact on the risk of falls in that group of patients [39].

Among women after breast cancer surgery, the observed trend of changes within the sagittal plane (increase in pelvic tilt symmetry) may translate into the stride length and be related to the walking speed. In that group, however, no significant changes in cadence or walking speed were found. The gait in women treated for breast cancer may have therefore become more conservative, which may be related to the self-perception. Sadeghi et al. [40] define gait symmetry as a consistent activity of lower limbs, during which the upper part of the body takes on stabilizing functions. Breast cancer surgery may cause postural freezing, thus increasing the symmetry. On the basis of the results obtained, it can be concluded that the group of women surgically treated for breast cancer is at the lowest risk of falling. However, population studies have shown that the risk of 2 or more falls within 1 year is 27% higher in postmenopausal women treated for breast cancer compared with healthy women [41].

Falls, however, are caused multifactorially; the factors can be divided into internal (associated with reduced fitness of the body) and external (independent of the aging process of the body). Internal factors include diseases, both acute and chronic [42]. Owing to the above, malignant tumours and their treatment are also mentioned among the reasons for the increased risk of falls. Usually, the relationship between complications and functional disorders resulting from oncological treatment and fall risk factors is mentioned. Among patients treated for cancer, reduction in bone density, decreased muscle strength, cardiorespiratory diseases, chemotherapy-induced neuropathies, fatigue and pain, as well as psychiatric disorders are observed both immediately after treatment and many years later [41, 43, 44]. Those disorders can largely affect the risk of falling.

Falls constitute a serious health problem, related with not only physical injuries, but also psychological consequences. It has been found that 48% of people who fall at least once are afraid of falling again, and 28% of people decrease their daily activity for this reason [44]. Therefore, in-depth examination of the causes of falls is needed. That is a particularly important problem among patients treated for malignant tumours, whose falls are usually multifactorial and occur more often compared with the corresponding age group without cancer history [45–48].

Knowledge of the occurrence of gait disturbances depending on the extent and site of surgery can therefore be helpful in developing methods for rehabilitation of patients, with the emphasis on obtaining improved balance and coordination. Fall risk reduction will consequently increase physical activity of patients after cancer surgery, which is of particular importance also for preventing side effects of cancer treatment.

Conclusions

1. In the group of patients operated on for reproductive and gastrointestinal cancer, a decrease in spatiotemporal gait parameters was demonstrated.
2. In the group of patients operated on for gastrointestinal cancer, a significant difference in symmetry of pelvic tilts in the coronal plane was observed.
3. The group of patients operated on for reproductive cancer is characterized by the greatest reduction of spatiotemporal gait parameters compared with the patients after gastrointestinal or breast cancer surgery.
4. Gait variability in cancer patients, which may translate into an increase in instability, indicates the need to prepare the patients to safely leave hospital environment.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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