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Gait pathology assessed with Gillette Gait Index in patients after CNS tumour treatment

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ABSTRACT

Brain tumour is the third leading cause of death in children and adolescents younger than 16 years of age. The increasing survival rate of these patients makes their follow-up and quality of life assessment an important task. This study evaluated the gait pathology of the patients after the combined treatment for central nervous system (CNS) tumours. It assessed if the severity of gait deviation depended on the tumour site or age of illness onset. Gait analysis was performed on patients who completed the treatment (neurosurgery, chemo- and radiotherapy) and were disease-free at the time of the study. One hundred and five patients, 42 girls and 63 boys, aged 5–24 years of age, participated in the study. Depending on the location of the tumour, patients were divided into six groups.

The Gillette Gait Index (GGI) was used to quantify gait deviation of patients compared to healthy subjects. Gait analysis was undertaken using VICON 460 movement analysis system. The Helen Hayes marker set was used, together with the Vicon Plug-in-Gait model. For each child the GGI was calculated separately for the left and right legs using data extracted from the subjects' averaged data. The results from left and right legs were then pooled together. To determine the effect of the tumour site and the onset of illness the ANOVA Kruskal–Wallis and correlation tests were used.

The GGI did not depend on the tumour site, but demonstrated significant gait pathology in all patients. The age of illness onset appeared to influence the severity of gait deviation.

1. Introduction

Progress in oncology treatment has rapidly improved the survival rate of patients with central nervous system (CNS) malignant tumours. In 1960s the survival rate was 10%, while in 1990s it increased to 60% [1]. In the paediatric population CNS tumours constitute 17–21% of all cancer patients, they are the third leading cause of death among children and adolescents younger than 16 years of age, and only leukaemia is more common [1,2]. Thus the quality of life of CNS tumour survivors has become increasingly important, together with the long-term effects of the oncological treatment. The treatment involves neurosurgery, followed by chemotherapy and radiotherapy. Such treatment causes a wide variety of adverse long-term effects, such as decline in IQ (with cognitive and memory problems), psychomotor impairment, encephalopathy, sensorimotor problems, neuroendocrine changes, and other complications [3].

Although functional deficits are known to be present in CNS survivors [1–3] little is known about them. The preliminary results of the gait changes and balance study [4,5] showed that these patients exhibit both gait and balance deficits. These deficits appear to be independent of the age of the illness onset, or on the site of the tumour, except for the patients with spinal cord tumours [4,5]. In this group the control of centre of pressure (COP) position during eyes closed condition required more vigorous control. The functional outcome depended on the time which elapsed between the end of the treatment and the time of the study. The relatively small number of patients (41) in the first study [4] led to limited conclusions regarding the gait problems of these patients. Therefore the aim of this study was a comprehensive evaluation of the gait deficits in CNS tumour survivors to determine whether the gait of these patients is changed in comparison to healthy children and adolescents, and to determine whether the gait abnormalities (if present) depend on the location of the tumour, age at illness onset, and the time between the end of the treatment and the time of the study. We hypothesized that the location of the tumour would lead to particular gait deficits, and that the gait deviations would depend on the age of the illness onset, especially if the onset was before the maturation of the gait pattern.

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The gait pathology was assessed with 3D gait analysis. Instrumented gait analysis provides a wide variety of spatio-temporal and kinematic parameters. An individual patient's gait can deviate from the normal pattern in many ways. The normalcy index, or Gillette Gait Index (GGI) [6], which is a single number, can quantify the overall amount by which a patient's gait deviates from the normal pattern, i.e. global gait pathology. The use of this index has been validated in cerebral palsy and idiopathic toe walker populations [6–8], as well as with respect to magnetic resonance imaging data [9]. Therefore, in this study, the gait deviations of the CNS tumour survivors have been evaluated with the GGI.

2. Materials and methods

2.1. Patients

One hundred and five patients participated in the study (42 girls and 63 boys). They were 5–24 years old. All patients were treated in the Department of Oncology, The Children's Memorial Health Institute (CMHI) because of the CNS tumours. The treatment comprised neurosurgical resection of the tumour, followed by chemo- and radiotherapy. The treatment was completed before the study, and all children were regarded as free from disease (confirmed by laboratory data, magnetic resonance imaging (MRI) and computed tomography (CT) scans). The time between the end of the treatment and the time of the study varied from 1 to 23 years (median was 5.1 years).

The inclusion criteria were:

- all patients underwent the combined treatment (neurosurgery, chemo- and radiotherapy), patients who received only one or two of these treatments (e.g. neurosurgery followed by chemotherapy) were excluded;
- they were disease-free at the time of the study; and
- they did not suffer from any other diseases (e.g. cardiological, diabetes, CP, etc.) before the onset of the illness.

No other inclusion or exclusion criteria were used. All patients visiting the Dept. Oncology between 2003 and 2008 for control check-ups were asked to participate in the study.

Depending on the location of the tumour patients were divided into the following groups: PF – posterior fossa tumours (47 patients, 16 girls and 31 boys), MID – midline tumours (21 patients, 9 girls and 12 boys), LH – left hemisphere tumours (12 patients, 7 girls and 5 boys), RH – right hemisphere tumours (10

Table 1
Summary of the kinematic variables (detailed description given in Appendix), Froude number, normalized step width, age at the illness onset and time between the end of treatment and the study in all subgroups. The variables are summarized by medians and ranges (5–95th percentiles).

	RH *N* = 10	PF *N* = 47	MID *N* = 21	LH *N* = 12	STEM *N* = 8	SC *N* = 4
Toe off (%)	62.4 57.8–72.3	61.7 58.1–68.3	62.0 59.5–69.6	61.75 58.8–70.7	61.3 56.5–70.7	60.7 58.8–70.1
Froude number	0.327 0.1–0.497	0.388 0.205–0.525	0.357 0.166–0.437	0.397 0.33–0.506	0.408 0.264–0.489	0.392 0.16–0.423
Normalized step width	0.571 0.322–1.349	0.622 0.324–1.22	0.545 0.404–1.098	0.589 0.314–0.867	0.736 0.407–0.837	0.765 0.454–1.241
Pelvic tilt (°)	8.5 2.0–19.0	9.0 0.0–15.0	10.0 2.0–15.0	8.5 2.0–12.0	5.5 −4.0 to 15.0	9.0 2.0–20.0
Range of pelvic tilt (°)	2.0 1.0–7.0	3.0 1.0–5.0	3.0 2.0–6.0	2.0 1.0–10.0	3.0 1.0–4.0	6.5 3.0–13.0
Pelvic rotation (°)	1.4 −4.0 to 13.0	0.0 −5.0 to 5.0	0.0 −6.0 to 9.0	0.5 −3.0 to 5.0	0.5 −4.0 to 5.0	−0.75 −30.0 to 9.0
Min hip flexion (°)	−13.0 −18.5 to 6.0	−11.0 −20.0 to 1.0	−8.5 −22.0 to 1.0	−14.0 −20.0 to −8.0	−9.5 −28.0 to 0.0	−5.5 −20.0 to 16.0
Hip range in sagittal (°)	39.5 29.0–51.5	41.0 28.0–48.0	40.0 28.0–54.0	44.0 37.0–53.0	42.0 30.0–52.0	41.5 35.0–51.0
Abduction in swing (°)	−1.5 −9.5 to 9.0	0.0 −8.0 to 8.0	2.0 −3.0 to 9.0	0.0 −6.0 to 6.0	0.5 −4.0 to 10.0	0.0 −8.0 to 12.0
Hip rotation (°)	−12.5 −40.0 to 9.0	−4.5 −30.0 to 20.0	−5.0 −37.0 to 18.0	0.0 −20.0 to 15.0	−5.0 −30.0 to 10.0	−7.5 −30.0 to 5.0
Knee flexion at IC (°)	5.5 −4.0 to 14.0	3.0 −4.0 to 14.0	4.5 0.0–16.0	3.0 −4.0 to 19.0	4.0 −4.0 to 17.0	8.0 3.0–22.0
Time to max knee flexion (%)	73.0 70.0–81.5	72.0 68.0–77.0	72.5 68.0–79.0	71.5 70.0–75.0	72.0 66.0–77.0	72.5 67.0–85.0
Knee range in sagittal (°)	51.0 37.0–60.0	52.0 39.0–66.0	52.0 26.0–68.0	59.0 48.0–66.0	52.5 38.0–67.0	52.0 42.0–64.0
Dorsiflexion in stance (°)	10.0 −10.0 to 21.5	14.0 8.0–22.0	13.5 6.0–20.0	14.0 3.0–19.0	13.5 6.0–30.0	14.5 2.0–23.0
Dorsiflexion in swing (°)	5.0 −18.0 to 10.5	6.0 0.0–13.0	3.5 −1.0 to 11.0	4.0 −2.0 to 7.0	4.5 −5.0 to 12.0	−7.0 −37.0 to 14.0
Foot progression (°)	−5.0 −21.5 to 4.0	−5.0 −20.0 to 4.0	−7.5 −21.0 to 6.0	−3.5 −18.0 to 10.0	−6.5 −15.0 to 4.0	−7.5 −25.0 to 8.0
GGI	195.31 56.83–486.58	142.87 47.29–343.35	171.97 48.44–335.08	106.81 23.96–289.33	157.2 32.54–282.5	110.64 46.44–967.01
Age at onset (years)	5.5 1.0–16.0	8.0 2.0–15.0	8.0 1.0–16.0	10.0 2.0–15.0	5.0 2.0–15.0	3.0 2.0–4.0
Time span (years)	4.5 1.0–23.0	3.0 2.0–11.0	3.0 2.0–10.0	4.0 1.0–8.0	4.0 3.0–16.0	7.0 3.0–9.0