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Functional recovery of gait after stroke.

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SUMMARY

Each year approximately 30.000 new stroke patients are reported in the Netherlands and due to the ageing population it is expected that this number will increase rapidly the next few decades. An estimated 70% of the patients who survive a stroke are unable to walk independently during the first few weeks post-stroke, therefore, regaining independent walking ability forms a major goal of all rehabilitation programs. The applied methods in rehabilitation programs are, however, primarily based on clinical and empirical experience over a long period of time; the scientific basis of these methods is rather poor. For the development of a modern rehabilitation medicine it is necessary that the employed treatment methods are firmly based on scientific principles. This goal can only be achieved when more knowledge is available concerning the mechanisms involved in the recovery of gait after stroke. The studies that are presented in this thesis were performed as part of a national program, which main goal was, therefore, to gain more insight into these mechanisms and to investigate to what extent they may be influenced. This thesis focusses on the recovery of kinematic and spatio-temporal gait characteristics and their relation with functional recovery of walking ability after stroke. Furthermore, the specific effect of neglect on the walking trajectory of stroke patients are investigated.

Chapter 1 provides a general introduction and an outline of the thesis. The main research questions that are raised in chapter one are:

- Is recovery of joint kinematics towards a normal pattern a requirement for functional recovery of walking ability?
- Is symmetry of gait a requirement for functional recovery of walking ability?
- Can compensatory gait patterns be detected, and if so, do they facilitate functional recovery of walking?
- If compensatory gait patterns develop in time, can it be predicted in an early stage *which* patients develop these patterns?
- What is the effect of neglect on the walking trajectory of stroke patients?

In **chapter 2** a low-cost ultrasonic motion analysis system is described that is capable of measuring temporal and spatial parameters while subjects walk on the floor. Four healthy subjects were included to test and validate the device. Subtracting positions of the foot with zero velocity yielded step and stride length. The duration of stance and swing phase was calculated from heel-strike and toe-off. Comparison with data obtained from foot contact switches showed that heel-strike and toe-off could reliably be calculated from the data. Although the device was validated on healthy subjects in this study, it promises to be extremely valuable in examining pathological gait. When gait is asymmetrical, walking speed is not constant or when patients do not completely lift their feet, most existing devices will fail to correctly assess the proper gait parameters. Our device does not have this shortcoming and it will accurately reveal asymmetries and variations in the patient's gait. As an example, the recording of a left hemiplegic patient is presented in the discussion.

The objective of the study described in **chapter 3** was to gain more insight into the relation between the changes in gait patterns over time and functional recovery of walking ability in stroke patients. Thirteen stroke patients who were admitted, or awaited admission, for inpatient rehabilitation three weeks post stroke and 16 healthy control subjects were included in the study. At 3, 6, 12, 24, and 48 weeks post stroke functional recovery of walking ability was assessed by means of the Rivermead Mobility Index (RMI) and the Functional Ambulation Categories (FAC) and, if possible, kinematics of the knee, hip and pelvis were assessed through gait analysis in an 8x4m gait lab. Patients required a minimal score of 8 on the RMI and 4 on the FAC to be classified as functionally recovered. The results showed that patients, whose joint kinematics during ambulation had recovered to within the range of the control group, all showed functional recovery of walking ability. However, some patients whose kinematics had developed towards an abnormal pattern also showed functional recovery. We conclude that the recovery of joint kinematics towards a normal pattern is not a requirement for functional recovery of walking ability. Early recognition of compensatory walking patterns facilitating functional recovery may have implications for rehabilitation programs.

In **chapter 4** we describe a study, which purpose was to determine whether symmetry in step length and single support duration is a requirement for functional recovery of walking ability after stroke. Thirteen stroke patients, admitted for inpatient rehabilitation three weeks post stroke, and 16 healthy control subjects were included to the study. At 3, 6, 12, 24, and 48 weeks post stroke functional recovery of walking ability was assessed by means of the RMI and the FAC. Patients required a minimum score of 8 on the RMI and 4 on the FAC to be classified as functionally recovered. Step length and single support duration were assessed by means of gait analysis while subjects walked at a self-selected comfortable speed. Patients whose step length symmetry and single support duration symmetry had recovered to values within the range of the control group, all showed functional recovery. However, several patients whose gait symmetry had not recovered to normal values did show functional recovery of walking ability. Therefore, it is concluded that symmetry in step length and single support duration is not a requirement for functional recovery of walking ability after stroke. Gait symmetry should be considered a rather questionable goal in stroke rehabilitation.

Degradation of major sensory systems such as proprioception, the vestibular system and vision may be a factor that contributes to the decline in walking stability in older people. In the study described in **chapter 5** this was examined by introducing a visual distortion by means of prism glasses shifting subject's view 10 degrees to the right while subjects walked towards a target (exposure condition). Shifting the view while walking towards a target will cause subjects to alter their heading in such a way that their walking trajectory describes a curvilinear path. It was expected that older people, when compared to young people, would have greater difficulty adjusting their heading and would show a greater decrease in heading stability, quantified by means of the standard deviation of the lateral position (SDLP). When performance in a pre- and post-exposure condition, in which subjects walked without prism glasses, were compared to each other, older people (O-group), indeed, showed a greater decrease in heading stability than young people (Y-group) and middle aged people (M-group). Furthermore, it appeared that during the exposure condition adaptation effects were present in the Y- and M-group, which were absent in the

O-group. It is discussed that this adaptation is a form of realignment of the proprioceptive and visual system. The absence of realignment in the O-group is argued to be caused by degradation of the proprioceptive system, which results in a lowering of the proprioceptive bias of vision.

A lateral deviation of the walking trajectory is often observed in stroke patients with unilateral spatial neglect. However, existing research appears to be contradicting regarding the direction of this deviation. The aim of the study presented in **chapter 6** was to gain more insight into the walking trajectory of neglect patients. Twelve right hemisphere stroke patients (6 neglect, 6 no neglect), 8 left hemisphere stroke patients (none neglect) and 10 healthy control subjects were instructed to walk towards a target while a two-dimensional ultrasonic positioning system recorded their walking trajectory. Patients' recovery of walking ability was assessed and they were tested for the presence of neglect. Neglect patients showed a larger lateral deviation in their walking trajectory compared to stroke patients without neglect or healthy control subjects. Neglect patients with good walking ability showed a deviation to the contralesional side. Neglect patients with limited walking ability showed a deviation to the ipsilesional side. Within the neglect group we found no relation between the severity of neglect and lateral deviation. Differences in walking ability may account for the contradicting results between studies regarding the lateral deviation in neglect patients' walking trajectory. We argue that when a neglect patient's walking ability is limited, walking towards a target becomes a dual task: heading control *and* walking. A limited walking ability will cause a lower task priority of heading control compared to walking, which results in a change of heading control strategy. This change of strategy may be causing the change in walking trajectory deviation.

Chapter 7 provides a general discussion, in which suggestions are made for future research based on the findings reported in the previous chapters, and a general conclusion, in which we attempt to answer the questions that were raised in the introduction. We conclude that neither the recovery of joint kinematics towards a normal pattern, nor symmetry of gait is a requirement for functional recovery of walking ability after stroke. Compensatory gait patterns can indeed

be detected and it appears that they are not by definition harmful, but may facilitate functional recovery. It is also possible to predict in an early stage which patients will develop compensatory gait patterns; at least for a stiff-knee gait pattern. Regarding the effect neglect has on the walking trajectory of stroke patients, we may conclude that when neglect patients actively maintain their heading, while walking towards a target, they will deviate to the contralesional side. However, when heading control changes to a “walking straight ahead” strategy this deviation shifts to the ipsilesional side.

