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Wearable Pressure Sensing for Vojta Therapy Guidance

Abstract: The authors propose a glove with pressure sensitive fingertips and muscle tension detection of the thumb to aid in the physiotherapy of infants, children and adults according to Vojta. The therapy has to be carried out at home by the parents of children with cerebral palsy, or other movement disturbances up to 4 times per day. Often, parents struggle to carry out the practices because of insecurities regarding the therapy's proper application. The presented glove is tailored towards the specific needs of Vojta therapy, e.g. flexibility and small sensor size, and can help parents gather objective data on their therapy application at home. It has been tested in multiple therapy sessions on adult probands and seems to be a suitable tool to support parents and therapists in training alike. Additionally, the results of the accompanied therapy sessions provide arguments against what the critics have often cited about the painfulness of the therapy.

Keywords: physiotherapy, training and further education, pressure sensing, wearable, therapy guidance

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1 Introduction

At the time of birth, all primary motor programmes are available in the central nervous system (CNS) [1]. The maturation of the CNS, the curiosity of the child and its longing for contact with its surroundings is increasing, which is reflected in all its developmental milestones.
At specific milestones, the typically developing child automatically uses the most efficient motor solution to fulfil his needs without conscious thought. Approximately 70% of all children use ideal postural and movement patterns to achieve this [2]. The Czech pediatric neurologist Prof. Václav Vojta described these patterns in detail and highlighted a certain stereotype e.g. in the first attempts to lift and hold the head, roll from supine to prone, crawl etc.
Children with a CNS disorder develop stereotypically as well, but in a different way. Access to the ideal movement patterns is blocked and every attempt to fulfil their desires ends up fixating their substitute patterns. Assessment of the spontaneous movements, the dynamics of the neonatal reflexes and postural reactions, forms the neurological examination according to Vojta.
Early diagnosis and therapy of movement disorders according to Vojta was founded on the empirical discovery of the innate activatable movement complexes, the so-called "reflex locomotion". This is the base of Vojta therapy.

Vojta therapy can be used from birth until old age. The repetitive stimulation of specific parts of the body is used to activate the innate ideal patterns which then appear in the children's spontaneous movements. The therapy must be applied up to 4 times a day for at least several weeks and can even extend up to many years. Like many other therapies focused on infants and children, Vojta therapy places considerable demands on parents. The authors propose a glove with pressure sensitive fingertips and muscle tension detection of the thumb to support parents that need to apply the therapy to their children. With this tool at hand they can compare their pressure levels to that of the physiotherapist.

2 Vojta Therapy

In Vojta therapy, motor functions such as crawling, sitting, grasping or walking are not trained. The innate movement patterns are activated without the patient's conscious intention. The coordination complexes *reflex creeping* and *reflex rolling* contain all the "building blocks" used for human posture and movement up until independent walking.

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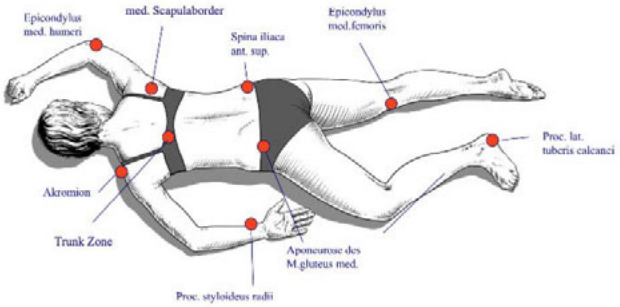

Figure 2: *Reflex creeping*: Starting position and possible zones that can be triggered.

Figure 1: *Reflex creeping*, triggering the heel zone (*processus lateralis tuberis calcanei*)

To activate these coordination complexes the patient is brought into specific starting positions, with exact angles within the extremities and in relation to each other. *Reflex rolling* proceeds from supine through side lying and ends in crawling. The starting position of *reflex creeping* is prone with the head turned to one side; the extremities are positioned as shown in Fig. 1. In this position, zones are pressed and the expected movement can be resisted or guided.

There are ten zones in total which can be triggered independently or in combination depending on the current position. Each of them is an anatomically defined point on the patient's body, located on a bone or muscle fascia. The zones have to be pressed in a certain direction, which correlates with the expected reaction.

For example, the *processus lateralis tuberis calcanei* is a bony point on the *calcaneus* (heel bone), which is normally triggered with the tip of the thumb, with the therapist's whole hand (or parent) held in high tension in order to direct and control the maintained pressure (see figure 1). In comparison the pressure applied to the *aponeurosis* of the gluteal muscle is much flatter and is applied more cautiously, as it tends to be sensitive, especially in adults. The parents, or caregivers carry out the treatment up to 4 times a day and therefore have a very important role in the implementation of the Vojta therapy. Together with their Vojta therapist they establish an individual programme, which has to be regularly supervised and adjusted. Besides learning to find the exact spot on the body and developing the ability to see and assess the expected reactions, they learn to trigger the zones effectively.

Not only the parents are carefully instructed in applying Vojta therapy. In the last 50 years, there have been over 5000 therapists only in Germany certified from the International Vojta Society. Certified Vojta therapists, doctors and treatment centers and clinics, where this therapy is practised and taught, are spread throughout the world.

3 Development and Demonstrator

As can be seen from the previous section, the application of the Vojta therapy can be complex at first. For parents there is only a comparatively short time to gather all the information and acquire the practical skills needed to successfully apply the therapy. Oftentimes, the therapy is strenuous for the children themselves and is acknowledged with considerable protest. This unsettles the parents as users even more.
Taking these thoughts into account, the development of a pressure-sensitive therapy glove means two things. On the one hand, the fears of the parents can be reduced by displaying objective data showing the actual pressure exerted on the activation points. On the other hand, the display of the pressure used serves as a comparative instrument. The home users can judge whether they press harder, lighter or comparably strong as the Vojta therapists and whether they consider the exercised and now visible activation pressure painful for their child.

The device shown in figure 2 consists of an open glove and a 3D printed housing for all electronic parts. The hardware consists of an ESP32 Development-Board and connected sensors used to record the applicants' pressure and muscle tension. Data is transmitted to the applicant's PC either with Bluetooth or WLAN. Pressure is recorded with a capacitive force sensor and muscle tension is recorded with electromyography (EMG).

The use of devices to measure exerted pressure in physiotherapy is not new. Several similar approaches have

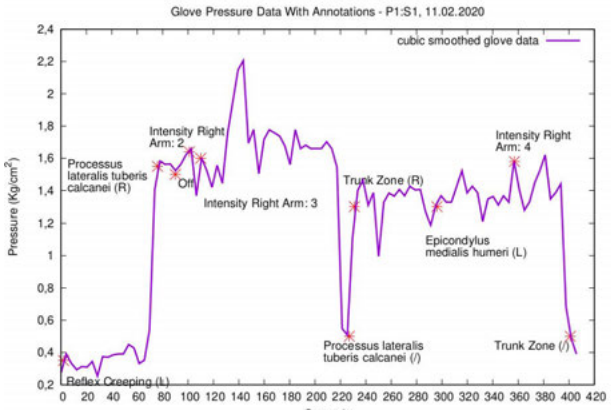

Figure 3: Annotated plot of pressure recordings of a seven-minute therapy session of an adult.

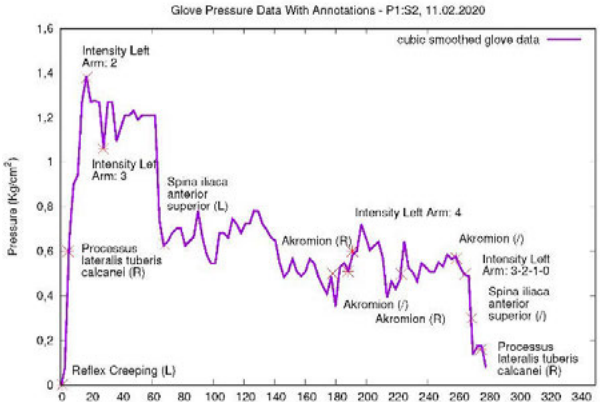

Figure 4: This graph shows, that sometimes activation rises, even when the applied pressure decreases (e.g. at 200 seconds)

been proposed over the years (e.g. [3] and [4]). The majority of those, however, would not be useful in the authors scenario because either of their size, low accuracy or functional constraints (see section 3.1).

Lately, some very interesting approaches for a pressure sensitive glove design have been published. Baribina et al. proposed a fabric-based pressure sensing glove [5]. We will closely watch the progress of those techniques and implement them as well in a next prototype.

3.1 Measuring Pressure

A particularly small, very flat sensor is required to detect the pressure exerted. Some of the zones in Vojta therapy are very small, comparable to a small lens in size (e.g. *processus lateralis tuberis calcanei*). A larger sensor would also lie on the surrounding tissue and thus influence the therapy application. The sensor used in the glove has a diameter of 8 mm and a height of less than 0.35 mm. The size of the sensor is also important to guarantee that certain activation points, such as the one between the ribs, remain accessible even in the case of infants. The thin structure is another important criterion for the application, as this is the only way to ensure that the therapists can feel the activation point and thus activate it in a required way. Previous tests have shown that three-dimensional sensors, larger capacitive sensors and a thicker glove over the fingertips made the application difficult to carry out. In the course of development, we have tried out various pressure-dependent resistors, whereby most of them do not allow linear sampling of the entire range of values due to their construction type. As a result, low pressures i.e. below 500 g/cm^2 are resolved well, but above 1 kg/cm^2 only very imprecisely. We finally found a SingleTact Sensor, which has linear characteristics and gives stable results even after extensive use.

The pressure data shown in figure 3 was recorded from a roughly seven-minute-long therapy application and has been cubically smoothed to suppress sensor jitter. All annotations to the data have been done by the therapists themselves and document the behavior of the patient in response to the therapy. As can be seen, the average pressure exerted is approximately 1.5 kg / cm^2 for an adult proband.

3.2 Measuring Muscle Tension

In addition to the recording of pressure, the authors measured the muscle tension of the applicant's fingers by using EMG. Through previous discussions with the therapists it became clear that the correct position and tension of the thumb is an essential criterion for successful activation. As has been shown in section 2, some zones have to be pressed flatter than other.

The thumb is the only finger that has a large part of its musculature in the hand and thus the only finger which's muscle tension can be measured in a glove like device that covers just fingers and the wrist. Two electrodes have been placed at the thumb muscles (*opponens pollicis*) and one reference electrode on the wrist. While the provided data can add additional information to the therapy performance its correlation to pressure levels could not be seen. It should also be noted that the values that have been obtained via the EMG circuit were strongly subject-dependent.

4 Results

Our investigations allow for several scientific results. First, it has been shown that by means of a pressure sensitive glove a valuable support for parents and Vojta therapists can be implemented. The main advantage compared to the current practice is that parents can reason about their application even when no expert is physically available. For ethical

reasons, the previous investigations were not carried out on infants and children, but only on adults. As a next step, we are planning a clinical investigation of a broader cohort to test the results presented here for their representativeness. In this study we will also include feedback from parents to further improve the system.

A second benefit of our research is to objectify the Vojta-therapy itself. The approaches used in earlier work were not suitable for investigating what pressure was applied to the subjects (e.g [6]). For adults, our measurements suggest that the pressure is relatively low and even decreases over the duration of the therapy. This is mostly the case if the intensity of the activation increases (see figure 4).
According to the findings of Davidson, Evalyne and McDougall most people experience pressure levels below 2 kg/cm^2 as not painful [7]. Pain created through pressure is of course highly dependent of the body region it is applied to. Because the physiotherapy according to Vojta is carried out only on skeletal and muscular structures, one can expect these values to be applicable nonetheless.

5 Summary and Further Work

In this article the authors presented a pressure-sensitive glove specifically adapted to the needs of the Vojta therapy. Parents, as laymen, are often in fear of applying the therapy incorrectly. The authors showed that the developed glove can detect the applied pressure and provide the parents with valuable information about a proper therapy execution. These pressure measurements could also provide the basis for statements on the amount of discomfort which may be caused through the therapy in general.

For ethical reasons, the glove has not yet been used for the therapy of infants and children, but only for adults. For future research we would like to expand the database by monitoring a larger, more diverse cohort of patients in therapy and by monitoring the correlation between pressure and activation success. We will also investigate to what extent such a device can be helpful in the training of future therapists that basically face the same uncertainty when starting their training.

Author Statement
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