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Device for the Limb Rehabilitation

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Abstract

Rehabilitation is a very important part of the patient convalescence after different types of diseases and accidents. The work presents the device for limb rehabilitation and proper arrangement of limb. Interdisciplinary and mechatronic approach to design were given the opportunity to prepare the universal concept of kinematic manipulator for limb rehabilitation

Keywords: crutch, kinematic structure, rehabilitation, anthropometry

1. Introduction

The purpose of this article is to present a new solution to the crutch. This crutch is a combination of a new construction of crutch and rehabilitation (diagnostic) system. Assumptions for the project were prepared on the basis of the analysis of the literature describing the current solutions, falls, suggestions of patients and therapists, the data on the rehabilitation and anthropometry.y depending on the age and sex [Gedliczka A., et al., 2001, Shoup T.E., et al., 1974, Winkler T., 2005, www.tuvie.com, 2014].

As a result of the disease or accident, lower limb does not function properly. Patient has problems with locomotion as he can't charge the weakened lower limb. In order to return a patient to movement ability, the rehabilitation involves reconstruction of lost movement patterns, through prolonged repetition of limb movement exercises. In traditional way, this type of exercise is carried out by a physiotherapist. Rehabilitation should be comprehensive. It should be realized all the time. After the move – exercises, patient uses a crutch to walk. After a preliminary analysis of the device (axillary crutch, forearm crutch or walking cane [Jung S., 2009, Ostrovsky G., 2009, Wolański N., et al., 1975, Zelinsky A., 2009, www.tuvie.com, 2014]) for this type of patients we discovered the lack of solutions that can meet their expectations.

To develop this new crutch it is necessary to prepare a preliminary analysis of the solution for this type of patients. It is possible to classify these solutions into the following groups of products:

- Classic solution (e.g. axillary crutch, forearm crutch or walking cane).
- Alternatives solution.
- Solution with diagnostic module
- Walking assist device.

Classic solutions (e.g. axillary crutch, forearm crutch or walking cane) have been around since the Pharaohs ruled Egypt some 5,000 years ago. Their construction didn't change. However, as a basic device of medical treatments, crutch design seldom changes. Most crutch design focus on the manufacture and price only and ignores other prospects as well. We all know these solutions so it is unnecessary to describe it.

Fig.1 a) Isowalk, b) S-upport efficient plastic crutch, c) Intelligent crutch (University of Southampton), d) iWALKFREE Hands Free Crutch, e) Free Spirit Knee & Leg Walker, f) Honda Walking Assist Device

Classic solutions are often prescribed as part of the recovery process for leg and ankle injuries. However, due to their size and their inconvenience, many crutch users find them impractical. Alternatives solutions are available to those who need them, though they are often under-publicized. In this group we can find crutches with more anatomic and comfortable design. (Isowalk [www.tuvie.com, 2014], 2011 Carbonium crutches [www.villadesign.it, 2019], S-upport efficient plastic crutch [www.tuvie.com, 2014], iWALKFREE Hands Free Crutch [www.goodbyecrutches.com, 2014], Free Spirit Knee & Leg Walker [http://justwalkers.com, 2014]). The iWALKFREE Hands Free Crutch is a unique product that completely reinvents the entire idea of recuperation.The iWALKFREE requires no hands at all to operate—simply strap it on, size it properly, and walk at a normal pace. The iWALKFREE allows the user to continue in many daily

activities that might otherwise be off-limits or unfeasible. This hands-free crutch requires good balance from the user, and may take some time to get used to (Fig.1d). Knee walkers are fantastic crutch alternatives intended for use with injuries below the knee. These innovative devices completely eliminate all the normal strain and effort of carrying around a pair of crutches. Sometimes called knee scooters, a knee walker has a padded platform on which to rest the injured leg, a complete set of wheels, and some form of steering device for one or both hands. The Free Spirit Knee & Leg Walker even comes complete with a transmission steering system and a custom carry pouch (Fig.1e).

There are only few solution with diagnostic module (Intelligent crutch (University of Southampton) [www.southampton.ac.uk, 2014], TechnoCan [www.technoconcept.fr, 2014]). We can find only few solution. Most of them are prototype. A physiotherapist and a computer scientist from the University of Southampton have teamed up to create an "intelligent crutch" that features force sensors and accelerometers. This smart crutch can provide info on its own movement and calculate the pressure that is applied to the leg. By processing the data, the device supposedly provides visual cues to the user when improper usage is perceived (Fig.1c).

Walking assist device has been developed to solve problems with locomotion for long distance (Honda Walking Assist Device [Bock T., et al.,2012], Cyberdyne HAL Robosuit [Zelinsky A., 2009], Toytoa Walk Assist Robot [Bock T., et al.,2012]).This type of devices are designed especially for older people. Sometimes they have problems with correct upright position and locomotion. These problem can finish fall down. The new Honda Walking Assist Device with the bodyweight support system reduces the load on leg muscles and joints (in the hip, knees, and ankles) by supporting a portion of the person's bodyweight. The device has a simple structure consisting of seat, frame, and shoes. Honda solution helps to reduce the load on the user's legs while walking, going up and down stairs, and in a semi - crouching position (Fig.1f).

After a preliminary analysis of the device for this type of patients we discovered the lack of solutions that can meet patient's expectations. There are deficiencies relating to providing comprehensive locomotion with hand free with diagnostic/rehabilitation system. One of them provide comprehensive mechanical design solution but they haven't any possibility to follow a rehabilitation process. For example Isowalk's hand grip inspired by fine bicycles. An adaptive force relief system (patented) conforms itself to each user's weight, pressure and specific gait. But all of this modification are insufficient in point of view rehabilitation reports. Another solution, Intelligent crutch (University of Southampton) provides this rehabilitation aspect with force sensors and accelerometers. But his design construction based on traditional axillary crutch. Another problem which is not presented very often is pain. It is not only pain which is caused by damages or diseases of lower limb. Using crutches, patient complains that his good leg hurts,

his hands hurt, his shoulders hurts and his armpits hurt. For these people not only architectural barriers can be a big challenge. Even a usual trip from point A to point B may be unattainable e.g. from the point of view of a patient, stairs might as well be mountains. Using crutches, a patient does not have free hands. He can take a book or two cups of coffee for his friends. Completing a user opinions, we found a very shocking statement that: "We can put a man on the moon but we can't make crutches that don't impale your armpits?!?" All of this statement brought us up to the challenge to develop a new crutch.

Before we started to design a new crutch, we wanted to know if epidemiologic data gives us the same confirmation as patient's opinions? In these data we discovered other very serious problems of people who use a crutch – fall. Falls which happen to elderly people and young people who have different kinds of problems with lower limbs or nerve system. Falls are rated in group of elderly people as, the so-called, the giants of geriatrics. Statistics are very bad. Such a great importance of these falls of elderly people originates in their consequences; almost 50% of them lead to injuries which, in many cases, are the reason for hospitalization, efficiency disorders and complications which lead to death. Among causes of these falls, there are external factors which are connected with the patient's surrounding and the internal ones which result from the process of the organism ageing, the already existing diseases and pharmacotherapy. According to epidemiological data, at least one fall in year has happened: 33% of people over 65 living alone, 20% of patients hospitalized, 50-67% of retirement home residents. 10 – 15% of falls cause severe injuries as wounds, intracranial hematoma. 5 – 6% of falls are different kinds of fracture (20% of victims die within 6 months after the fracture). 50% of patients who move before the injury lose this ability and need care [Alison M., 2010, Skalska A., 2011].

2. Project

Our project foresees to design a new crutch to relieve lower limb and rehabilitation. This crutch is prepared with a view to patients after neurological or orthopaedic injuries. The major objectives of the project are as follows:

- Prepare new construction of crutch to reduce a user's pain.
- Realize walking with crutch without using upper limbs.
- Diagnosis and continuous monitoring of performance (biofeedback).
- Safety.
- Low cost of implementation.

Based on the information from the first part of the article, as well as having additional interdisciplinary skills, two concepts of crutch were proposed. These

concepts have the same base but their supports are different. These supports depend on kind of injuries (e.g. knee, ankle, hip dysfunction). The base is grey color (Fig. 1 – 2). The base was designed in accordance with the requirements of lower limb correct alignment

Concept I consists of adjustable curved tube, supports of the foot, leg, thigh (Fig. 1). These supports have ergonomic design to reduce pain. The supports are of green color. This solution was designed for people with knee or ankle injuries. This concept replaces the axillary crutch.

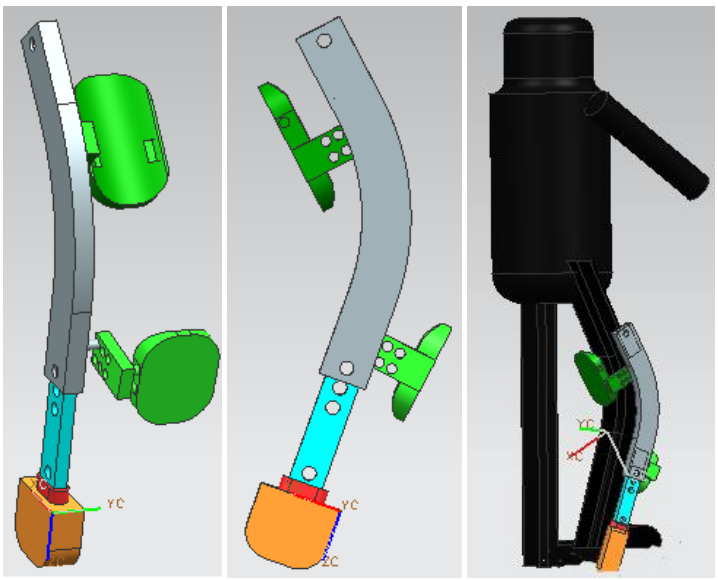

Fig.1 Solution I of crutch

In order to increase the group of potential patients (hip dysfunction), concept II (Fig. 2) in presented. This concept has also support of the pelvis. The support of the pelvis is of yellow colour. In this concept we changed the shape of the end of the crutch (brown color). It was designed for patient with foot drop. It is very common dysfunction after stroke. This concept replaces the axillary crutch or forearm crutch.

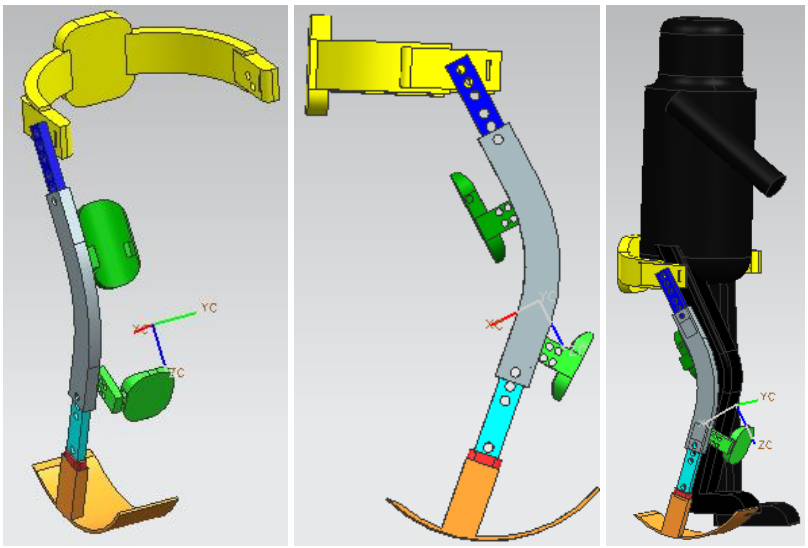

Fig.2 Solution II of crutch

Additionally patients receive a new solution to make their life easier. In case of the concept I and II, patient has hands free. This solution is more practical and comfortable for daily use. It is possible to regulate the basic dimensions in order to obtain the correct position and individual approach to the patient. We can change dimensions of high or leg parts (blue and ocean color) and the position of supports.

Moreover patients receive a new solution to help their rehabilitation. The end of crutch ground reaction force measurement system and inertial measurement unit (IMU – red color) sensor is integrated to monitor human motions (Fig. 3). The level of abnormality in motion is evaluated for the purpose of rehabilitation. Patient receives a new biofeedback system. When the value of force are lower, it means that patient starts charge and walking with his weakened lower limb. He starts to use crutch less. Biofeedback and implemented of motion which occurs in the proper performance of the movement. In all cases the damage requires reconstruction through the rehabilitation process. All of these data and reports can be sent to therapists. Therapist coordinates the rehabilitation process. With this solution it is possible to conduct rehabilitation exercises all the time when patient is trying to walk. Not only during meeting with therapist. Patient uses our crutch to relieve the weakened lower limb and he receives tool for recover his health by working on himself.

In this solution we don't use motors because most of our patients have no problem with moving their lower limbs. But the doctor recommended to relieve this lower limb or patient starts charge and walking with his weakened lower limb. During this convalescence, he wants to know if rehabilitation is well prepared and if it's helped him.

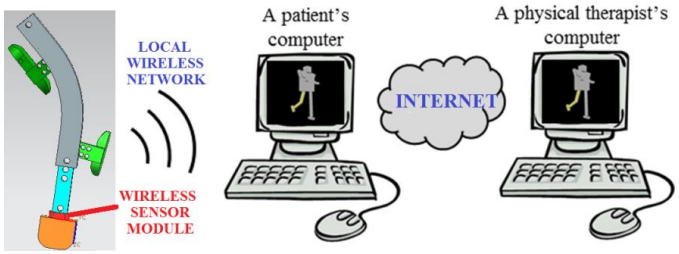

Fig. 3 Biofeedback system in crutch

Moreover in our solution we use only one sensor because we want to receive only a ground reaction force. This information allows us to define if rehabilitation is proper. We do not need to use the e.g. 5 sensors for the foot because this kind of information isn't required in these dysfunctions. Our patient correctly puts the foot during gait but does not have enough force. This solution can be extended with additional sensors easily.

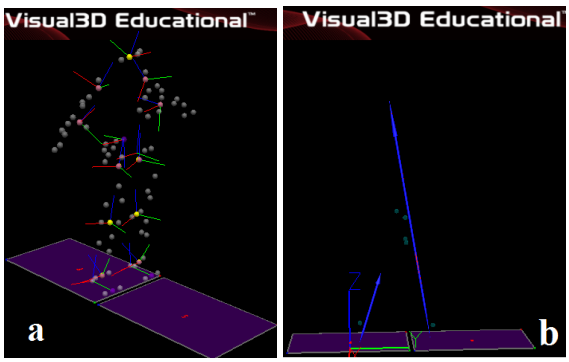

Fig.4 a) Model of the user, b) forces reaction during gait

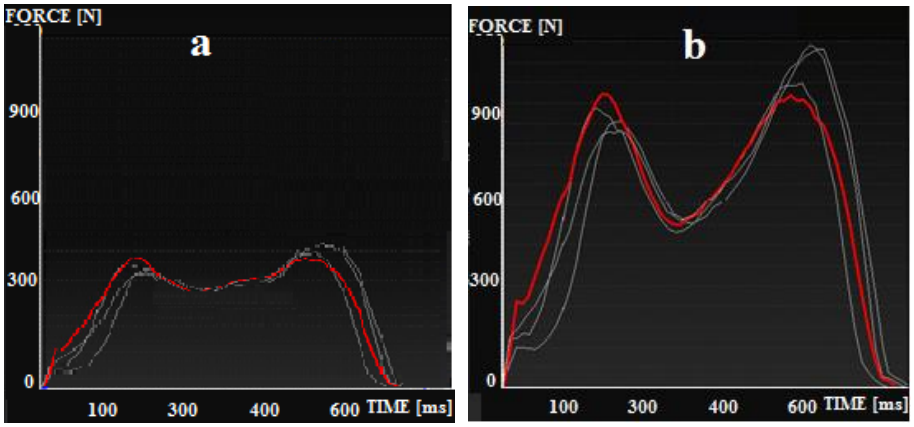

Fig.5 Vertical ground reaction force curves of right lower limb; a) patient with lower limb dysfunction; b)patient after successful rehabilitation

Fig. 4 presents model of the user. Interesting software for this kind of simulation is Visual3D (C-Motion). It is the 3D analysis toolkit with possibility to perform 3D biomechanics modelling and analysis. To analysis our concept I or II, it is necessary to receive a information about vertical ground reaction force. In the first part of rehabilitation process, patient don't want to loading ill leg. He uses to a greater extent crutch (Fig.5a). Vertical ground reaction force curve has smaller values and this curve is float during midstance of gait cycles. During the rehabilitation process, patient learns how to loading ill leg and correct gait. He can analyze his rapports and try to walk better. If he uses crutch less, his vertical ground reaction force curves will have shape and value like natural gait.

3. Conclusion and discussion

The design of our solution is a hybrid of a crutch and rehabilitation tool. Our patients have problem with walking or balancing. We propose a new design crutch. He doesn't use a upper limb for locomotion. His upper limbs are free. This solution gives patient a possibility of a comfortable life. His life is more flexible.

Second, this allows patients to control ground reaction force. This biofeedback system allows patients to analyze and correct their locomote. This is a continuous rehabilitation during a daily activities. Additionally patient can sent this information to his therapist.

The title of this article has deliberately word rehabilitation. We wanted to state that rehabilitation doesn't only realize with therapist, but this process should be fulfill all the time. Using our crutch patent receives new solution for continuously rehabilitation.

During the development process of the crutch, we paid attention to the overall costs and requirements of patients / therapists. Thanks to this, rehabilitation will become more friendly for the patient. Additionally the therapist receives a new system to control a rehabilitation process all the time when patient uses a crutch. Our innovative crutch has ability to make patient life easier and recover a health by working on yourself.

At the beginning of the project presented some objectives. Now we would like to present a few observations on the basis of this solution. Our solution reduce a user's pain through exchange axillary support and handle to supports of the foot, leg, thigh in concept I and additionally the support of the pelvis in concept II. This provided a larger surface area on which the force is acting. Furthermore skin on thigh and leg is less sensitive to damage than the axillary. For all users the most important thing is realize walking with crutch without using upper limbs. Our solution in concept I or II has this ability. Introduction module therapist diagnosis and continuous monitoring of performance (biofeedback). It gives a possibility to get better to user and therapist. In our solution we can measure ground reaction

force. This information allows us to define if rehabilitation is proper (biofeedback). Information about costs is presented below.

This type of device requires the manufacture of relatively small expenditure of raw materials and energy, and waste which receive are easy to dispose of. At this stage of the project, we cannot define exact costs. These costs relate to the implementation of simple construction with supports, pressure sensor and wireless node microcontroller. Our solution will be more expensive than the traditional crutch (iWalkfree 150euro) but cheaper than knee walker 650euro. In press information News Release on June 3, 2013 we can read that Honda plans to improve their functions toward commercialization [16]. Now Honda want to lend this devices to 50 medical institutions for a year for under 300euro per month. Now we can only guess what will be the high price of this device.

This is a first article about our new crutch. In this work we want to present a huge problem that is ignored and considered insignificant. We want to receive a opinion about our solution. Now this concept is modify to receive individual approach to patient. Additionally we prepare a patent application for newest version. After this process we will present another articles with this modification and test with users.

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