Original article

"Right & Left Scissors Angles" measured by Honda Motor's "Walk Assist" robotic rehab instrument act as accurate indicators of humans' walking ability and the "Walk Assist" help doctors record and analyze characteristics of Gait Cycles at both post-stroke hemiplegic patients and healthy persons

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Abstract

Objective: A post-stroke hemiplegia often afflicts the elderly, for which rehabilitation is the most effective treatment measure. Until recently, the assessment of whether such patient's walking ability has improved or not as a result of rehabilitation has been performed only on the basis of the visual observation of the patient's gait by doctors and therapists.

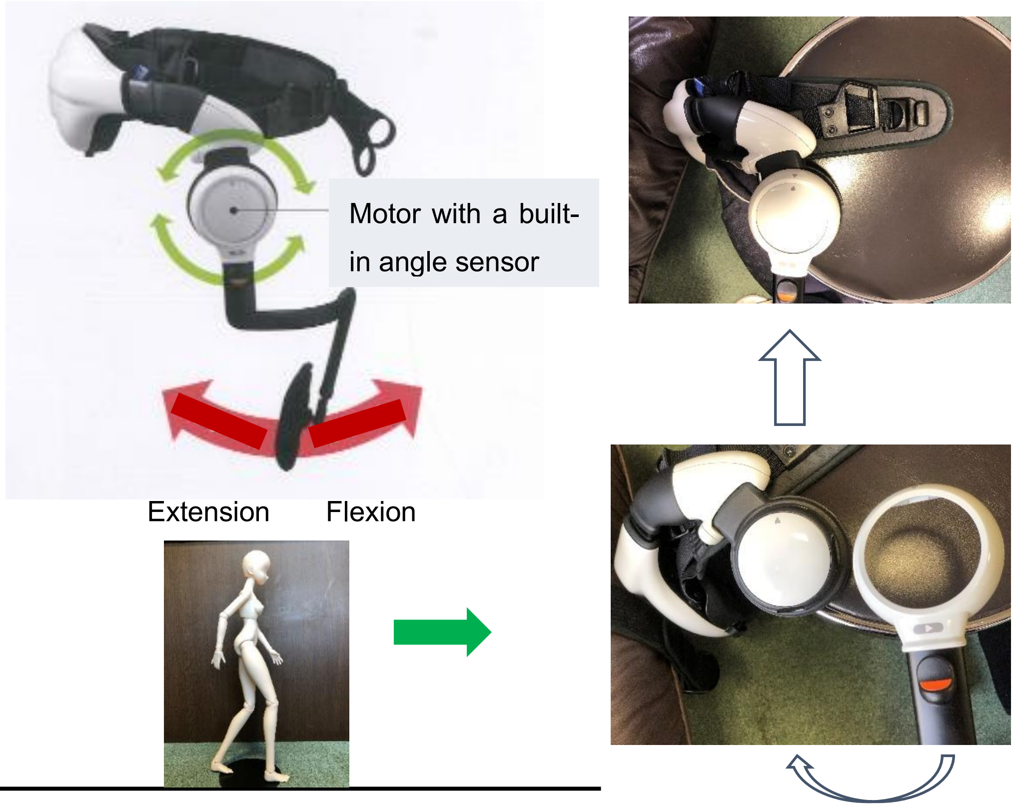
The purpose of this paper is to demonstrate the usefulness of the "gun belt-shaped" robotic rehab instrument of Honda Motor Co. in measuring and recording the "Right Scissors Angle" and "Left Scissors Angle," which act as accurate indicators of degrees of paralysis at the right or left legs of a post-stroke human who developed a hemiplegia at the right or left side of his or her body.

This lightweight rechargeable battery-powered instrument, which Honda Motor calls "Honda Assist," is a set of an ultra-thin computer-fitted hip frame and two thigh frames, which are fastened to a patient's body with two Velcro belts and a waist clasp around the patient's waist and left and right thighs. This Velcro belts and clasp make the device easily detachable after each rehabilitation training session. Let us call the device the "Honda Walking Assist (HWA)" in this paper from time to time to clarify the device's purpose. (See the attached photographs and explanatory diagram that show the instrument's shape and its wearing position around the navel on Pages 101, 134, 137, 138 and 139)

Our previous study of March 1, 2019, showed that the HWA can improve the walking ability of post-stroke hemiplegic patients and therefore facilitates the rehabilitation of such people with gait deficits. This paper's study, which showed the good results of 16-month rehabilitation efforts for a hemiplegic patient fitted with the HWA, again made evidence of the instrument's ability to improve the walking ability of post-stroke hemiplegic patients.

Two electronic angle sensor-fitted motors are fixated to both sides of the gun belt-shaped hip frame, which is installed at the opposite side of the navel. At first glance, the two motors, fitted right above the right and left greater trochanters – namely, just above the center of a person's right and left hip joints -- look like the two guns of a cowboy picture's gunman which are suspended from the gun belt's both sides like holsters.

Figure 1. HONDA ASSIST



When this walker advances in the green arrow's direction, Honda Assist's right thigh frame pulls her right leg forward in the direction. Please note the shape of its right-thigh rod in the side view of the assist above. The initial part of the rod stretches downward from the motor. **But it is bent toward the front of her thigh at its first bend-point. Compare the two photos. This rod shape enables the pulling force to be imparted to the right leg from the moment when her right foot raises of the ground –** and throughout the right leg's swing -- until the moment when it is positioned for initial foot contact with the ground**. Shortly after the foot strikes the ground, an extension phase for the right leg begins with the frame starting to push backward and extend the leg in the opposite direction.** The left thigh frame works likewise.

Honda Assist's simply package configuration consists of:

Rechargeable battery-fitted hip frame that straps onto wearer's waist.
2 motors that lie above right and left greater trochanters.
Two thigh frames that strap onto R & L thighs.

Computer that controls thigh frames' swing torque and angle.

Short slender alloy rods, which stretch straightly downward from each of the two motors, impart a computer-controlled torque – more precisely, a forward-and-backward swinging force -- to the thigh frames, which are fixated onto the right and left thighs from above the wearer's clothes (usually, trousers or pantaloons) with a hook-and-loop fastener. The fastener is known as the “Magic Tape” in Japan and as the “Velcro“ overseas.

Through the intermediary of the rod, the HWA imparts the forward-or-backward swinging forces to a wearer's thighs via its thigh frames. The rods are propelled by the motors like a swing “as if a pendulum of a grandfather's old-day clock moved a pendulum bob forwards and backwards.”

This kinetic support from the computer-controlled motors, which have the shape of a flat cylinder that looks like a woman's round powder compact, is continuously provided throughout multiple gait cycles until the walker reaches his or her destination point.

While a usual pendulum oscillates as a result of the universal gravitation that works on the swinging bob's mass which is initially displaced sideways from its equilibrium and resting position, the HWA facilitates and supports the legs' flexion and extension on the basis of kinetic power generated by the motors which are propelled by electric energy stored in the lithium ion batteries.

The HWA incessantly communicates to a wearer's right and left thighs optimal forward or backward swinging forces, which are determined by the computer that determines the most fitting values for the forces that are commensurate with each phase of the wearer's gait.

A forth-or-back swinging forces from the motors are carefully optimized by the hip-frame computer, because it constantly observes the state of the patient's gait by measuring what Honda calls the “Right Scissors Angle (RSA)” and “Left Scissors Angle (LSA)”, as well as degrees of symmetry between the RSA and the LSA. Now let us call this degree of LSA-RSA symmetry the “degree of left-right symmetry,” because we have to refer to the measures of this symmetry degree repeatedly in assessing degrees of rehabilitation of the walking ability attained at a post-stroke hemiplegic patient fitted with the HWA.

Other parameters of a gait cycle like the patient's walking speed and his movable hip-angle range are also monitored and taken into accounts by the computer in determining optimal swinging forces that should be given to the walker's legs at each moment of his gait cycle.

A HWA wearer's movable hip angle range, the passage of time from the start of a rehabilitation session, his walking speed and other gait characteristics are also constantly monitored and recorded by the robotic gadget.

The hip frame, thigh frames and a monitor screen-fitted mini tablet come as a package with the HWA, enabling doctors, therapists and patients to grasp, check and analyze patients' current state of gait, degrees of left-right symmetry and degrees of improvements in their gait and the left-right symmetry after each rehabilitation training session.

Honda defines the "Left Scissors Angle (LSA)" as the sum of the left leg's maximum flexion angle (X) and the right leg's maximum extension angle (Y).

In other words, the LSA is the sum of (X) and (Y) angles…where (X) is the angle formed when a walker's left thigh reaches its peak forward advancement – thereby forming the maximum flexion measure of angle between the supposed center straight line of the left thigh's femur and the perpendicular drawn from the left greater trochanter toward the ground -- and where (Y) is the angle formed a moment before or after (X) is made, when the walker's right thigh reaches its peak backward extension angle with the walker pushing off his right foot on the ground to lift it off from the ground, thus forming the maximum extension measure of angle between the right femur and the perpendicular drawn from the right greater trochanter toward the ground.

In greater details, Honda computers the LSA by dividing the cumulative sum of all maximum flexion angles attained by a walker's left thigh and all maximum extension angles attained by the walker's right thigh when he walks down a standard distance by the number of gait cycles logged by the walker during a span of time which the walker needed before he completed walking down the standard distance.

Honda also defines the “Right Scissors Angle (RSA)” as the sum of the right leg’s maximum flexion angle (A) and the left leg’s maximum extension angle (B).

In other words, the RSA is the sum of (A) and (B) angles…where (A) is the angle formed when a walker’s right thigh reaches its peak forward advancement -- thereby forming the maximum flexion measure of angle between the supposed straight center line of the right femur and the perpendicular drawn from the right greater trochanter toward the ground -- and where (B) is the angle formed a moment before or after (A) is made, when the walker’s left thigh reaches its peak backward extension angle with the walker pushing off his left foot on the ground to lift it off from the ground, thus forming the maximum extension measure of angle between the supposed center line of the left femur and the perpendicular drawn from the left greater trochanter toward the ground.

In greater details, Honda computed the RSA by dividing the cumulative sum of all maximum flexion angles attained by a walker’s right thigh and all maximum extension angles attained by the walker’s left thigh when he walks down a standard distance (for example, five meters) by the number of gait cycles logged by the walker during a span of time which the walker needed before he completed walking down the standard distance.

Now, suppose a situation where a doctor is observing the gait of a post-stroke hemiplegic patient who is trying to walk straight forward from the left to the right when viewed from the observing doctor on the floor of a nursing-care facility or a hospital.

Readers are then asked to conjure up the image of the mid-sagittal plane which the patient is now making, while advancing in the right direction. The sagittal plane cuts vertically through his body from anterior to posterior, dividing it into right and left halves.

Now, please conjure up the images of para-sagittal planes which divide his body into unequal right and left parts.

You are then asked to imagine the two types of para-sagittal planes that incorporate the three-dimensional points of the patient's right and left greater trochanters, which lie exactly beneath the powder compact-shaped motors of the Honda Walking Assist.

To facilitate a clear understanding of the usefulness of Honda Walking Assist in assessing and rehabilitating a person's walking ability through the use of an analogy, the authors decided to use the terms "Left Scissors Angle (LSA)" and "Right Scissors Angle (RSA)" to call readers' attention to the concept of "scissors," which is, of course, a cutting instrument made of two blades, pivoted so that the cutting edges can be closed on what is to be cut.

Let us liken each of a walker's two greater trochanters to the pivot of scissors, while the supposed straight center lines of his femurs can be compared to the instrument's cutting edges.

When the walker is observed from his side, his two femurs can be likened to the legs of an "isosceles triangle" due to the sameness of the lengths of the legs at this type of triangles, while each of his right or left greater trochanters acting as the pivot can be compared to the vertex.

Although measures of the angle included by the two legs constantly increase or decrease while the walker advances, the plane figure formed by the walker's femurs and the vertex is, or is similar to, an isosceles triangle in cases where the walker's both legs are simultaneously in the stance phase, or (in other words) when he is in the double (bipedal) support phase.

This is the reason why the authors decided to use the terms – the Left and Right "Scissors" Angles (LSA and RSA).

Observing the two types of scissors angles from the side of a post-stroke hemiplegic patient fitted with the robotic assist (or a person with a normal walking ability fitted with the assist) when they walk through the sagittal plane **enable** observers to accurately grasp and analyze the measures of the angle made by these persons' two femurs.

In other words, the magnitude and amplitude of the angle made by the two femurs including the vertex can be grasped and recorded by the assist's computer. These records, their computer memories and resultant print-out papers enable the observers to analyze the characteristics of the gait of the observed.

It is crucial for doctors and therapists engaged in rehabilitation of post-stroke hemiplegic patients to grasp how widely and amply a walker can open his or her two legs and usually do open them, with his or her hip joint functioning as the vertex of such an isosceles triangle.

Technically, the Honda Walking Assist, in measuring the RSA and the LSA, effectively "**projects"** the perpendiculars drawn from the two greater trochanters to the ground and the supposed straight center lines of the right and left femurs **onto the two planes on which the motors move the thigh frames forwards and backwards repeatedly like a swing** to help the patient flex or extend their thighs, and thereby their legs.

This projection enables the computer to measure, grasp and record an examinee's constantly-changing measures of flexion and extension angles formed by the projected two perpendiculars and the projected femur lines that now swing on the motor planes.

This projection enables the instrument to accurately measure the RSA and LSA at patients and healthy examinees, while allowing it to continuously capture and put on record the measures of angles formed by their femurs and such perpendiculars. These measures of angles constantly fluctuate by either ascending or descending as a walker goes through various phases of his gait cycles.

This feature also allows the robotic assist to display on its tablet's screen, record and print out a subsequent line graph drawn by sets of numerical coordinates on the graph's X-axis and Y-axis on the Cartesian coordinate system, with readings on the X-axis representing the passage of time and those on the Y-axis representing measures of angles. This facilitates observation and analysis by doctors and therapists.

This projection is necessary to enable the instrument to track and measure constantly-changing flexion and extension angels made by right and left legs with its sensors, which are incorporated inside a motor module, rather than inside a human's hip joints. As a matter of course, the sensors cannot be surgically implanted into a human's hip joint. Still, the robotic assist's projection capability enables the RSA and LSA to be measured accurately.

The two planes on which the motors move their rods lean on each other like the legs of a very tall isosceles triangle, or like the two sides of the alphabetical letter of an "A" as a result of the presence of a human's subcutaneous fat at their thighs.

If readers kindly remember how the two legs of the Eiffel Tower extend toward the sky in the tower's multiple postcards, it may help them graphically evoke the image of the mutual reclination of the two motor planes in their minds. Despite the mutual reclination, the robotic assist's projection feature enables the LSA and RSA to be measured accurately.

While measuring these measures of angles, the battery-powered Honda Assist imparts optimal amounts of back-and-forth swinging forces for each gait phase and moment to the thighs through its thigh frames suspended from the motors "as if a grandfather's old-day clock moved a massive bob forward and backwards." And the HWA does so tirelessly and optimally unlike human therapists who can develop fatigue as a living creature.

This kinetic-energy support is continuously provided throughout multiple gait cycles until the walker reaches his or her destination point. In so doing at multiple rehabilitation training sessions, the Honda Assist goes on improving a post-stroke hemiplegic patient's walking ability by strengthening the patients' muscle functions and teaching such patients how to walk with greater degrees of left-right symmetry. This in turns stimulates and starts a crucial "learning process" about how to walk correctly, or with greater L-R symmetry degrees, on the part of patients' brain.

While a pendulum oscillates as a result of the universal gravitation that moves the bob's mass after it is initially displaced sideways from its equilibrium , resting position, the assist's metal rods, which extend downward from the motors, facilitate and support the legs' flexion and extension by continuing to impart the optimal forward-and-backward force, while the sensors observe and grasp the phases of the walker's gait constantly.

What is noteworthy is that the Honda Assist helps observers of post-stroke hemiplegic patients to accurately grasp, understand and analyze the characteristics of the patients' walking patterns, which are represented as measures of the two angles -- the "RSA" and "LSA" – and other smaller measures of angles that are incessantly formed by the two femurs throughout a gait cycle.

In Japanese, HONDA Motor calls the RSA "Migi Hasami Kaku" and the LSA "Hidari Hasami Kaku." In Japanese, the word "Hasami" signifies a pair of scissors. "Migi" means the right, while the "Hidari" signifies the left. The Japanese word "Kaku" signifies an angle.

After applying careful considerations, the authors have decided to translate the "Migi Hasami Kaku" as "Right Scissors Angle," while rendering the "Hidari Hasami Kaku" as "Left Scissors Angle." Let us note here that Honda presently appears to prefer the terms "Right Crossing Angle" and "Left Crossing Angle" to the RSA and the LSA amid our respect to their hearty intention to apply their robotic technology for the benefits of society and the rehabilitation of post-stroke hemiplegic patients. Still, we have decided to use the translation terms RSA and LSA in this paper in order to ensure an easier communication of the meaning of the two terms to readers in English-speaking countries.

In this paper, the authors have evaluated if the notions of the "right and left scissors angles" are universally useful and helpful in bolstering the efficacy of rehabilitation efforts now being made worldwide at numerous nursing-care facilities for post-stroke hemiplegic patients, because they would like to open the path for a widespread use of the Honda Walking Assist which is capable of providing very efficient and strong help to doctors and therapists now striving to facilitate such patients' rehabilitation to improve their walking ability.

We hope that this study will help give such doctors and therapists a great success, namely, the type of significant walking ability rehabilitation which we have witnessed at our nursing-care facilities for the elderly when we applied the HWA to poststroke hemiplegic patients.

Subject and Method:

The characteristics at a sequence of phases during the gait cycles of both a female with a normal walking ability and a male post-stroke hemiplegic patient, both of who walked a standard distance of five meters on the flat ground at our rehabilitation center, were grasped, recorded and analyzed with the Robotic Rehab Instrument HONDA ASSIST®.

Resultant data on the characteristics shown by the two persons enabled a compassion and analysis of the data.

Data of the female was collected on August 2, 2018, to check if the robotic assist has an ability to accurately evaluate the characteristics of a person's gait and the degrees of left-right symmetry as defined in this paper (See Pages 102 and 127). During this data collection occasion, we did not let the robotic assist apply a torque (forward-and-backward swinging force) to the female's thighs via its motors and alloy rods to impart such torque to the assist's thigh frames.

Meanwhile, data of the male post-stroke hemiplegic patient were taken on May 17, 2018, and then on October 8, 2019. On both occasions, his data were taken in two manners – by both **actuating** the HWA's motors to apply such torque to the patient's thighs **and refraining from actuating** the motors.

Checking if the HWA is useful in rehabilitating a poststroke hemiplegic patient's walking ability requires comparing data on changes in a patient's walking ability before and after several months of HWA-based rehabilitation training.

Verifying if the HWA has a strong capability to improve such patient's walking ability requires confirming that the patient can demonstrate a significant improvement in his walking ability , especially in terms of degrees of his right-left gait symmetry, even after doctors switched off the actuator to keep the HWA from applying a torque to the patient's thighs.

Results:

In checking the usefulness of the HWA, the authors used the method just described above after administering a HWA-based 16-month rehabilitation training to the 72-year-old male hemiplegic patient, starting on May 17, 2018. Rehabilitation training was given to the patient twice a week, with each training session lasting for 30 minutes or so. The actual duration of time during which he walked with the aid of the HWA came to several minutes at each session.

The characteristics of the gait cycles of the two persons – the patient and the female with the healthy walking ability -- were recorded and analyzed with the aid of the Honda Assist. We confirmed that the HWA accurately measured, recorded and displayed the gait cycle characteristics at the two persons on both the instrument's tablet-style screen and print-out papers.

Data similar to the data taken from the two examinees on the duo's respective days of examination concerning their gait cycle characteristics are reproducible even if each of the two undergoes further rehabilitation or rehabilitation trial sessions in the coming weeks or months -- and even if data were taken and analyzed at different places and on different days.

Data that attest to the HWA's ability to evaluate and improve the gait cycle characteristics and walking ability at poststroke hemiplegic patients is reproducible even if the robotic instrument is applied to poststroke hemiplegic patients other than the examinee at our study -- at different locations, at different times and at different facilities.

Such data collection would make evidence anew of the usefulness of the Honda Walking Assist in evaluating and improving the characteristics of the gait cycles of post-stroke hemiplegic patients, as well as their walking abilities assessed in terms of their degrees of right-left symmetry, the notion that will be further explained in the subsequent pages of this paper.

Conclusion:

We concluded that the HWA can be used to measure, evaluate, quantify, analyze and rehabilitate efficiently the walking ability not only of post-poststroke hemiplegic patients to whom this apparatus has been already applied, but also of post-stroke hemiplegic patients who have not yet been given access to this robotic instrument.

The rehab instrument's usefulness is augmented by the lightweight and the easy-to-handle natures of the instrument that use only two "Magic Tape" or Velcro hook-and-loop fasteners to fixate it to patients' thighs, alongside a waist clasp.

It is appropriate to conclude that **"**Right & Left Scissors Angles" measured by this instrument can work as accurate indicators of humans' walking ability by helping observers of post-stroke hemiplegic patients understand, record, print out and analyze the characteristics of gait cycles at the observed.