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Tyler Champagne

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The Examination of Hip Joint Kinematics with iWalk in Walking Gait

TYLER CHAMPAGNE

Abstract

The purpose of this study was to examine the kinematic movements of the lower limbs involved in walking with a new hands-free crutch known as iWalk, manufactured by iWalkFree Inc. Recently, this new crutch has been developed to reduce underarm stress from conventional crutches, and improve walking efficiency. This study examined the movements with the iWalk by simulating a lower limb injury to the right lower limb in ten healthy female individuals in order to evaluate the kinematics of walking gait, specifically the hip joint angle of the non-weight bearing limb. The results of the study showed a significant increase in hip flexion angle when iWalk was used during the heel strike (145.1 ± 6.6°), mid support (149.2 ± 8.5°), and toe off (155.8 ± 10.7°) of the walking gait. Therefore, the design of the hands-free crutch has been found to alter the walking gait while in use. This increase of the hip joint angle may lead to an increase in the internal joint force and torque at the hip, which may increase the likelihood of developing a patellofemoral pain with continued use over an extended period. Future studies are warranted to examine the 3-D motion analysis and internal force and torque at the hip joint with the use of iWalk.

Introduction

One of the most fundamental forms of human locomotion is walking. Gait refers to how each body part performs while walking. A normal gait may be affected when one experiences a lower extremity injury such as hip replacement surgery, knee replacement surgery, ankle sprain or amputation. To re-enable this crucial movement in the individual, the primary pieces of rehabilitative care equipment utilized by hospitals are traditional underarm crutches. An average of 6.5 million people uses an assistive device such as crutches to assist with mobility in the United States alone (The Centers for Disease Control and Prevention, 2012). Beekman and Axtell (1987) indicated crutches are encouraged by therapists and thought to be less cumbersome and more versatile for patient use. Traditional underarm crutches are used by placing the crutch pads underneath the armpits, holding onto the hand grips, and balancing on one leg while using the crutches to accommodate ambulation for the non-weight bearing side. This process has been used and widely accepted for years: however, it is quite an impractical process.

Traditional underarm crutches are difficult to use, and if used improperly, can potentially result in further injuries to the body (Oran, Parildar, & Memis, 2000). One significant challenge that arises when using crutches is inability to use the arms, in addition to the already immobilized leg. Essentially, functionality is lost in three of the four limbs. This makes simple everyday tasks such as opening doors and traversing stairs quite troublesome and challenging for the individual. Traditional crutches reduce the independence of the individual and make life much more difficult than need be. They also pose a risk for numerous injuries simply based on the design (Choi, Ahn, Ryu, Kang, Jung, Park & Shin, 2015). Due to the pressure placed on the underarm during crutch use, compression of the brachial plexus occurs. The brachial plexus is the network of nerves surrounding the neck region that break off and form nerves that run down the upper limbs and control sensation and movement in these limbs. More specifically, compression of the radial nerve which is a branch from the brachial plexus arises and can cause pain, tenderness, and motor weakness (Choi, Ahn, Ryu, Kang, Jung, Park & Shin, 2015). Crutches also affect the ulnar nerve, which can become entrapped and lead to further complications. The ulnar nerve may become compressed at the axilla by the crutches; compression of the ulnar nerve can lead to nerve damage and neuropathy (Jacobson, Fessell, Lobo, &Yang, 2010). When attributing this to crutch operation, this is referred to as crutch palsy, or crutch paralysis.

In humans, it is believed that symmetrical walking gait helps maintain upright positioning and forward propulsion. When the walking gait is rendered asymmetrical, injuries arise from additional stress and force being put onto one leg due to muscle imbalance. Gouwanda (2014) indicated that asymmetrical walking gait leads to lower back pain, osteoarthritis, and a higher potential of falling. Further, Nadler et al. (2001) found lower back pain is quite a common occurrence in female collegiate athletes due to musculature imbalance between the two sides of lower extremity. The researchers conclude that imbalance derives from a stronger right or left abductor gluteus medius muscle, and a stronger right or left extensor gluteus maximus muscle. This imbalance would lead to asymmetrical walking gait which results in a higher potential risk for lower back pain and lower limb injuries (Nadler et al., 2001). Increased incidences of lower extremity injuries were discovered in athletes with right knee flexors or extensors 15% stronger than the left (Knapik, Bauman, Jones, Harris, & Vaughan, 1991). In order to counteract the problems put forth by outdated, impractical, underarm crutches, as well as attempting to prevent asymmetrical walking gait, a new form of crutch has been released onto the market known as the iWalk Free.

The iWalk, is a new form of crutch that is hands-free, completely eradicating the stress applied to the underarm area from traditional crutches, **Figure 1**. This, in theory, will minimize the secondary effects and injuries of underarm crutch use previously mentioned; impractical design, hand requirement, and nerve damage. The device allows individuals to travel up and down stairs and have full use of the hands to assist in the process. The iWalk engages the upper leg muscles of the injured leg to prevent muscle atrophy which could result in an imbalance of the gait. Furthermore, it is easier to store and transport due to its smaller size and lighter weight. Due to the recent release of the iWalk, there is a lack of empirical evidence on its effects in relation to walking gait. Therefore, the purpose of this study was to examine the symmetry of walking gait with iWalk. The

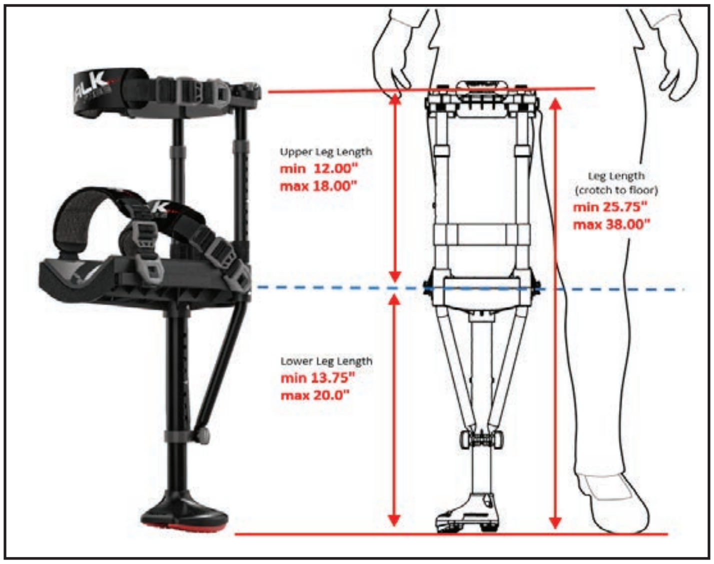

Figure 1. Fitting guide for the iWalk Hands-Free Crutch.

results of this study will provide further knowledge about the effects of walking gait with an assistive device and also inform medical practitioners about whether the iWalk is a beneficial and feasible replacement of traditional underarm crutches for patient use.

Methods

Ten healthy, injury-free University female students with an average age of 20.2 ± 1.6 years old were recruited to participate in the study. Prior to the study, IRB approval was acquired, and written informed consent was obtained from each participant. All participants received a confirmation E-mail and phone call prior to appointment date to ensure participation. Each participant arrived at the Biomechanics Laboratory at specific times throughout the day to ensure enough time for each individual. Each participant was allowed to warm up first by stretching and walking on the treadmill. Then, ten joint reflective markers were placed on both sides of the body at the shoulder (gleno-humeral joint), hip (greater trochanter of the femur), knee (lateral epicondyle of the tibia), ankle (lateral malleolus) and toe (base of the fifth metatarsal). The participant then walked barefoot on a treadmill at a speed of 1.03 meters per second for thirty seconds, **Figure 2.**

Then, each participant was fitted to the iWalk device, which was tailored to each individual using the fitting manual, **Figure 1**. The knee of the non-weight bearing limb was adjusted until it was symmetrical with the weight bearing knee with a slight outward angle. They each put on the device and placed feet shoulder width apart with the help of an assistant. Once the individual could stand on their own for 30 seconds, and were capable of walking in the device without assistance, they began walking on the treadmill at the same speed of 1.03 meters per second, **Figure 2.**

The treadmill was located in the middle of the Biomechanics Laboratory with high speed Casio cameras (Model EX-FH25) positioned to capture the sagittal views of both right and left sides at 120 Hz. Two 650W artificial spot lights were used in conjunction with each camera to assist in joint marker identification. All video trials were transferred onto a Bridgewater State University computer in the Biomechanics Lab for gait analysis. Three successful walking gait cycles were used for analysis. The instant of heel strike, mid-foot support and toe off of the walking gait at the hip joint was analyzed in order to determine how much of a difference in normal walking gait the iWalk had on the individuals. A two-dimensional kinematic walking gait analysis was conducted with Aerial Performance Analysis System (APAS™) motion software. A total of 360 trials (10 participants x 2 conditions x 2 sides of the body x 3 gait cycles x 3 phases of gait) were analyzed, which

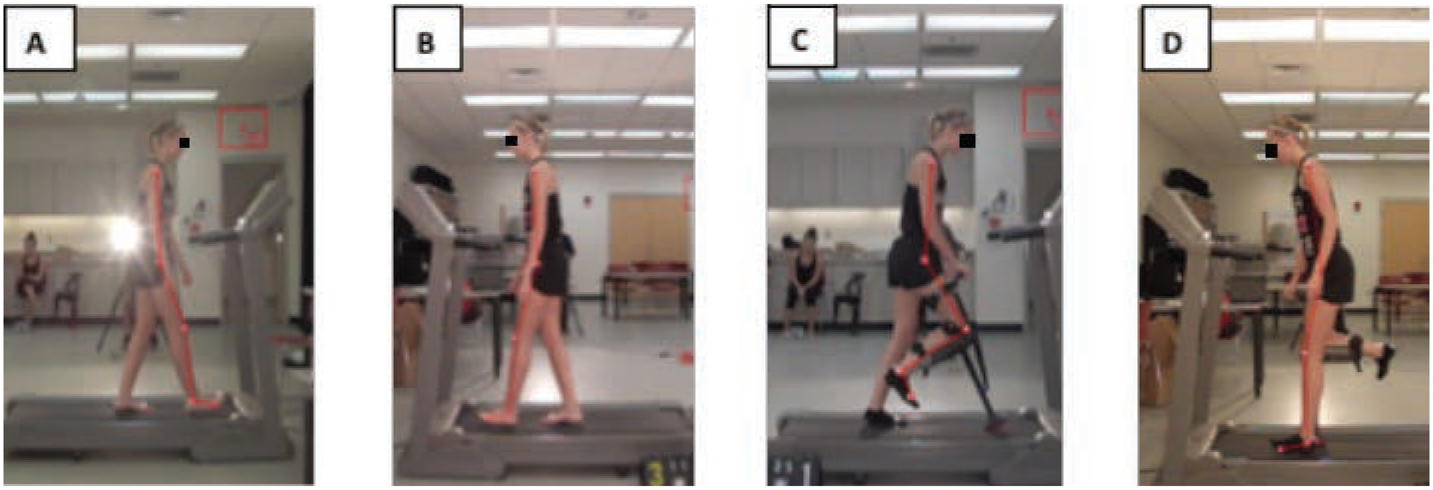

Figure 2. Heel strike phase during walking gait: A) Right side barefoot view, B) Left side barefoot view, C) Right side iWalk view, D) Left side iWalk view.

is typical in a biomechanics research study. Dependent sample t-tests were conducted with Bonferroni adjustment and all statistical analyses were conducted with SPSS software.

Results

Using SPSS software, dependent sample t-tests were conducted with Bonferroni adjustment ($\alpha = 0.05$ / # of comparisons = 0.05 / 4 = 0.0125) between right and left side iWalk as well as right and left side barefoot walking on the treadmill for each participant during heel strike, mid support, and toe off phases. Angular displacement of the hip was observed and analyzed using a dependent sample t-test where statistical significance was found at ($p < 0.0125$). This statistical comparison of data showed that the angular displacement of hip joint iWalk and barefoot at heel strike, mid support, and toe off as follows.

Table 1. Hip joint angle at heel strike. Data are means (SD).

Right Barefoot	159.6° (5.7°)
Right iWalk	145.1° (6.6°)
p	0.00
Left Barefoot	156.4° (6.2°)
Left iWalk	155.6° (7.8°)
p	0.45

Table 2. Hip joint angle at mid support. Data are means (SD).

Right Barefoot	171.7° (5.6°)
Right iWalk	149.2° (8.5°)
p	0.00
Left Barefoot	169.7° (6.8°)
Left iWalk	164.9° (8.3°)
p	0.01

Table 3. Hip joint angle at toe off. Data are means (SD).

Right Barefoot	174.1° (3.9°)
Right iWalk	155.8° (10.7°)
p	0.00
Left Barefoot	172.6° (4.6°)
Left iWalk	172.5° (5.9°)
p	0.96

These results showed that the iWalk does indeed cause an alteration to normal walking gait. The testing parameters which were affected were, as stated above, the right iWalk vs Barefoot hip angle at heel strike **(Table 1),** right iWalk vs Barefoot hip angle at mid support **(Table 2),** left iWalk vs Barefoot hip angle at mid support **(Table 2),** right iWalk vs Barefoot hip angle at toe off **(Table 3),** and right iWalk vs Barefoot hip accelerationat toe off **(Table 3).** The iWalk changed the hip angle by an average of 18 degrees on the right leg, while it altered hip angle merely 1.9 degrees on the left leg.

Discussion

The iWalk hands-free crutch is a newly released ambulatory device with little to no research supporting its benefits or hindrances. The device was released to deter further use of traditional underarm crutches due to the bodily harm they can cause. The purpose of this study was to examine the lower-limb gait with the iWalk crutch, more specifically to get a better understanding of how the iWalk affects the hip angular displacement while walking on a treadmill. The hip joint is one of the most substantial joints while performing ambulation. During normal walking, stress is applied to the hip joint because it's an area in which multiple muscles and ligaments attach. Jacobsen, Nielsen, Sorensen, Soballe & Mechlenburg (2014) describe the point of most tension on the hip by stating, "hip flexor muscles form the joint moment of hip flexion together with the joint capsule and the strong capsule ligaments at the end of the stance phase, where the leg is in maximal hip extension. In this position, maximal tension is put on the passive and active structures on the frontal side of the hip." In this study, Jacobsen et al. (2014) discuss the stress applied to the lower limbs during walking in individuals with hip dysplasia. They used 32 individuals and discovered by using a 3-D motion capture system that the peak flexion moment was different in individuals recovering from hip dysplasia surgery compared to the healthy individuals.

The hip joint is an imperative component to walking in individuals, and because the iWalk alters the angle of this joint, it will lead to further issues for the individual. The hip angle of the limb in the iWalk device was consistently shown to be lower than without the device. It is believed this is due to the added weight of the device. Thus, it is necessary to change the normal walking gait to compensate for this additional weight of the limb with the assistive device by increased hip flexion movement from possible greater stride length in walking gait of the non-weight bearing limb. The smaller hip angular displacement means that the leg is in flexion for a longer period with this weight, which may result in more stress applied to the hip joint and further asymmetry to the gait.

Seeley (2011) states that despite changes in underarm crutch design, repetitively inducing high magnitude forces to the upper extremities during traditional crutch ambulation often leads to upper extremity pathologies, while also requiring approximately twice as much metabolic energy as healthy walking. This study involved 10 male and 10 female participants and intended to find a healthier alternative to traditional underarm crutches by using another form of crutch as well. The spring-loaded crutch has a singular spring in the crutch post which is designed to store and return mechanical energy to the patient, which would in theory help propel the individual forward. The individuals walked at an average speed of 0.97 m/s on each type of crutch on a solid ground surface. They then used a paired *t* test to compare sample means between the two crutch designs. They proved there were more difficulties associated with crutches, but found no significant differences between the traditional crutches and spring-loaded crutches ($p = 0.396$). Despite the results, this research provides supporting evidence that there needs to be a healthier alternative to underarm crutches.

While performing research there were some limitations encountered which could not be controlled. During walking with the iWalk some participants were uncomfortable in the device walking on a treadmill which resulted in holding onto the treadmill for added safety. This could have affected the resulting data. Time restraints resulted in a lower amount of time per participant to get accustomed to the device. If the participants were given more time to get used to the device, the results may have been more substantial. A delimitation put into place was the speed of the treadmill. The speed of the treadmill was set to a manageable speed that should have been a comfortable walking speed, while still maintaining normal walking gait. Another delimitation of the study was choosing to only analyze recordings of the left and right sides of the participants. Additional variables which could be added for a future study could be a rear- view camera to provide three-dimensional data, as well as male and female participants from various age groups, to fully encompass all individuals and to report more substantial results.

Conclusion

This study used ten healthy female students in order to examine the lower limb effects of using the hands-free crutch at heel strike, mid support, and toe off phases of walking gait. This study provides a basic understanding as to why an alternative to traditional underarm crutches are necessary. The results showed the iWalk does result in a significant change to the individual's hip angle when compared to normal barefoot walking.

This could result in an asymmetrical walking gait with extended use. Therefore, this study concludes the iWalk hands-free crutch will alter walking gait. Future studies are warranted to examine lower limb kinematics with both genders over a longer period to address long term use issues.

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About the Author

Tyler Champagne is a graduating senior pursuing Physical Education with a concentration in Motor Development Therapy. His research was a continuation of a pilot study performed under the mentorship of Dr. Tom Wu (Movement Arts, Health Promotion, and Leisure Studies). This research was funded both by the 2016 Spring Semester Grant as well as the Adrian Tinsley Program Summer Research Grant. Tyler eagerly anticipates presenting this research in the summer of 2017 at the American Society of Biomechanics in Boulder, Colorado. He plans to pursue his degree in Occupational Therapy.