RELIABILITY OF A TESTING PROTOCOL TO EXAMINE THE EFFECT OF SPRING LOADED CANE MECHANISMS ON UPPER AND LOWER EXTREMITY GROUND REACTION FORCES, MUSCLE ACTIVITY, AND EASE OF USE DURING GAIT

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The purpose of this pilot study was to assess the reliability of a testing protocol to examine differences between spring-loaded and traditional canes for future research. Healthy participants (n=20) were fitted with a T-Scope knee brace and three types of canes. Each participant walked over two force plates, where EMG, force and impulse data were collected. Participants also completed an Ease of Use questionnaire. Five trials were performed using each type of cane. Intra-class correlation (ICC) values were calculated for all dependent variables. All ICC values were greater than 0.7, indicating a high level of reliability. The Ease of Use questionnaire had a high level of internal consistency, as determined by a Cronbach's Alpha of 0.834. Future research will examine causal links between spring-loaded and traditional canes and improvements in the measured variables.

KEY WORDS: canes, force, upper extremity

INTRODUCTION: Findings reveal that approximately 6.6 million individuals living outside of institutions use mobility aids (Kaye, Kang, & LaPlante, 2000). Of these mobility aids, canes are by far the most widely used devices, with approximately 19% of these individuals using canes in the U.S.

Canes are often prescribed to improve people's mobility and help them maintain balance while performing activities of daily living. By decreasing weight bearing on one leg, canes may also help alleviate pain from injury or clinical pathology (e.g., hip fracture, arthritis), or compensate for weakness or impaired motor control of the leg (e.g., from stroke) (Bradley & Hernandez, 2011). Additional clinical benefits ascribed to cane use include improvement of balance control due to a widened base of support and increased somatosensory feedback (Tagawa, Shiba, Matsuo, & Yamashita, 2000). Clinical observation and empirical evidence, however, suggest a high prevalence of disuse and abandonment of mobility aids (Becker, Glad, Nebelsick, & Yernberg, 2013). Becker et al. (2013) reported that 30-50% of individuals abandon their device moments after receiving it. Problems associated with cane use reported in clinical literature include discomfort, pain, and injury in the upper limb (Koh, Williams, & Povlsen, 2002; Schemm & Gitlin, 1998). Several modifications have been made to the standard single-tip support cane since its emergence in order to address these concerns. Of these modifications, the addition of a spring loading mechanism to the shaft of the cane is the most novel and least researched. The addition of the spring mechanism is hypothesized to store the energy of the impact from cane strike and use this elastic energy to provide propulsion after the mid-stance stage of ambulation (Liu, Xie, & Zhang, 2011). This cycle of storing and releasing mechanical energy is thought to reduce the magnitude of the impact during the initial contact phase and propel the body after mid-stance. Furthermore, the spring mechanism is hypothesized to reduce extra push-off being exerted by the upper extremities after mid-stance, thereby reducing the incidence of upper extremity injuries (Liu et al., 2011); however, research on such mechanisms in canes is currently limited to testimonials.

Given this gap in the existing literature, there is a need to conduct further research to establish a causal relationship between spring loading mechanisms in canes and decreased forces on the upper extremities. The purpose of this pilot study was to assess the reliability of a testing protocol that we will use in the future to examine differences between spring-loaded and traditional canes in minimizing upper extremity overuse injuries. The preliminary findings of this pilot study may also have implications for future research design methodology to study populations with lower extremity injuries and to further explore possible causes of cane abandonment and disuse.

METHODS: Research design. Pretest-posttest design.

Data Collection. Prior to data collection, ethical approval was obtained from the Lakehead University Research Ethics Board. Data was collected at Lakehead University and took approximately 90 minutes of time for each participant. Healthy participants (n=20) completed two testing sessions. The purpose of the initial session was to ensure individuals met the inclusion and exclusion criteria. The second session involved formal data collection. During the preliminary meeting, participants were given a letter of recruitment, letter of informed consent, Par-Q, and a general demographic questionnaire. The general demographic questionnaire included data regarding the participants' height, weight, gender, program of study, and presence of any condition listed in the exclusion criteria.

When participants attended the second session, wireless EMG electrodes were attached to the surface of their skin to measure muscle activity. The electrodes were secured by way of adhesive pads overlying the following muscles: flexor carpi radialis, extensor carpi radialis longus, brachioradialis, and triceps brachii. Specific placement of the EMG electrodes followed procedures outlined by Criswell & Cram (2011).

Following EMG electrode placement, the participants were fitted with each cane (traditional, Miracle Cane®, and Stander Cane®) and a T-scope knee brace, and given a chance to practice proper cane walking technique. Canes were fitted by ensuring an elbow flexion angle of 15-30 degrees when the participant was standing and the cane was in contact with the ground. The T-scope knee brace, which was fitted to the participants' dominant legs, was used to limit knee extension (by creating a unilateral 30 degree knee flexion contracture) and simulate an antalgic gait pattern. Participants were then allowed to practice walking to minimize hesitancy in maneuvering and to familiarize themselves with the device. This familiarization period took approximately 10 minutes.

Once the participants were comfortable with cane use, they were asked to walk over two force platforms, each with six degrees of freedom. That is, three forces (Fz, Fx, Fy) and three moments (Mz, Mx, My). For this pilot study, the force platforms were used to measure vertical, braking, and propulsion ground reaction forces. For each type of ground reaction force, impulse was calculated under the cane tips and the leg with the T-scope knee brace. Participants were asked to perform the cane-assisted walking technique using the three different types of canes. For each of the conditions (traditional, Miracle Cane®, and Stander Cane®), the participants were asked to perform 5 trials. A trial was considered valid if the participant hit the force plate with the complete base of the cane and no secondary impacts were present. Secondary impacts referred to any other impacts of the base of the cane or adjacent foot to the force plate. Furthermore, if the participant hesitated or broke natural stride in any manner, the trial was not considered for analysis and the participant was asked to repeat the task again.

Each trial was performed at self-selected walking speeds, but were required to fall within a range of 1.25-1.50 m/s (Usroads, 2015). Limiting the speed that the participant walked at ensured that any variation in ground reaction forces were not influenced by the speed at which the force was applied. The speed of walking was monitored by setting up timing gates around the force plates.

Subject and cane kinematics were also recorded using a video camera in this testing session. Kinematics were analyzed through simple observation in order to ensure that participants were striking each force platform with the complete base of the cane and foot. Trials that failed to do so were excluded from the analysis.

Post data collection, participants were given a questionnaire to assess subject-perceived ease of use for each type of cane.

Data analysis. Impulse, EMG, walking speed, and force plate data were collected for each of the 5 trials for each cane condition. Intra-class correlation (ICC) values were calculated for all dependent variables across all types of walking canes using SPSS for Windows. A one-way random effects model was used. Comparing values obtained across trials provided a measure of test-retest reliability.

All collected data was grouped based on cane condition (traditional, Miracle Cane®, and Stander Cane®). Force and impulse in the vertical (Fz) and anteroposterior (Fx) directions were also grouped based on extremity used (upper or lower). Electromyographic data was grouped based on muscle type (flexor carpi radialis, extensor carpi radialis longus, brachioradialis, and triceps brachii).
Cronbach's Alpha statistic was also run in order assess internal consistency of questionnaire measures for the Ease of Use questionnaire.

RESULTS: Table 1 shows the results from the ICC procedure for all dependent variables, grouped accordingly. Intra-class correlation values ranged from 0.715 to 0.981, indicating strong correlations between trials for all measured variables. The Cronbach's Alpha statistic yielded a value of 0.834.

Table 1
Summary of ICC Values for All Dependent Variables

Dependent Variable	Traditional Cane	Miracle Cane	Stander Cane
Force			
Fz Force Lower Extremity	0.968	0.981	0.969
Fz Force Upper Extremity	0.880	0.851	0.908
Fx Force Lower Extremity	0.903	0.822	0.880
Fx Force Upper Extremity	0.753	0.715	0.768
Impulse			
Fz Impulse Lower Extremity	0.946	0.968	0.967
Fz Impulse Upper Extremity	0.741	0.927	0.938
Fx Impulse Lower Extremity	0.902	0.81	0.902
Fx Impulse Upper Extremity	0.919	0.915	0.733
Electromyography			
Brachioradialis	0.708	0.884	0.775
Extensor Carpi Radialis Longus	0.839	0.887	0.797
Flexor Carpi Radialis	0.731	0.724	0.879
Triceps Brachii	0.926	0.900	0.928
Time			
Timing Gates	0.819	0.916	0.930

DISCUSSION: It is well documented in measurement literature that to test a hypothesis and make inferences from test result interpretations, it is critical to assess and provide evidence of reliability of the measures obtained from the instruments and testing protocols (Kane, 2006). The outcome of this pilot study revealed that all ICC values were greater than 0.7 and demonstrated strong correlations between values collected from the force platforms, EMG sensors, and Brower timing gates. The Ease of Use questionnaire had a high level of internal consistency, as determined by a Cronbach's Alpha of 0.834. Since all participants were healthy individuals, the variability between ICC values (0.7-0.9) for various measures may be explained by participants' ability to ambulate with a cane-assisted device. As the results indicate, upper extremity measures often resulted in greater variability than lower extremity measures due to greater variation in the pressure applied to each cane; however, it is important to note that these measures were still highly reliable in healthy participants.
The findings of this pilot study provide evidence that these measures are an accurate and precise method assessing force, impulse, EMG, walking speed, and perceived ease of use during cane-assisted locomotion. This method can be used in future research to assess differences between traditional and spring-loaded canes with regards to the aforementioned kinetic variables.

CONCLUSION: The purpose of this pilot study was to assess the reliability of a testing protocol for a future study examining differences between spring-loaded and traditional canes. The method used in this pilot study to assess differences in springy and traditional canes was highly reliable. Future research will examine causal links between spring-loaded and traditional canes and improvements in the magnitude of ground reaction forces, impulse, levels of muscle activity, and self-reported ease of use, as an avenue to minimize upper extremity injuries. The findings of such research may have implications on the rate of abandonment of current cane designs by allowing practitioners to make appropriate recommendations with regards to the best cane design, which minimizes the negative effects of repetitive stresses on the upper limb.

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