THE EFFECT OF A SPRING LOADED CANE ON UPPER AND LOWER EXTREMITY GROUND REACTION FORCES

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The purpose of this study was to examine the effect of a spring loading cane mechanism on upper and lower extremity ground reaction forces during cane aided walking. Twenty-nine participants were fitted with a T-scope knee brace and a cane with four spring loading compressions. Each participant walked five times over two force plates to collect ground reaction force data. A mixed factorial ANOVA revealed a significant interaction effect between spring cane loading compressions and extremity on measures of ground reaction forces, $F(1.68,94.18)=5.56$, $p=.008$, $\eta 2=0.090$. This outcome suggests that ground reaction forces decrease at the upper extremity via the cane shaft as the spring loading compressions of the cane decrease. This result may have implications for injury prevention and rehabilitation in cane aided walking.

KEYWORDS: Canes, ground reaction forces, upper and lower extremity.

INTRODUCTION: Canes are used to assist patients with weight bearing, balance, and locomotion issues. Canes are often prescribed to improve mobility of stroke survivors, patients with weakness of the lower limb, and patients with lower limb fractures (Ajemian et al., 2004; Lam, 2007). Bateni, Heung, Zettel, McIlroy, and Maki (2003) found that using a cane during rehabilitation aids in reducing the load placed on the injured leg and minimizes the risk of further injuries. The long-term use of a cane, however, may generate negative effects on the upper extremity leading to pain and overuse injuries of the wrist, elbow, and shoulder joints (Son et al., 2012). In addition, it may detract patients from gradually weight bearing on their paretic leg increasing rehabilitation time and cost (Son et al., 2012). Some of these concerns, however, have been minimized by the development and implementation of spring loaded cane designs. This approach is believed to store the energy of the impact from cane strike and use this stored energy to propel the body forward after the mid-stance stage of the walking cycle (Zhang, Liu, Xia, & Liger, 2011). Furthermore, the use of spring loaded canes may reduce upper extremity ground reaction forces induced via the cane shaft; consequently, reducing the risk of upper extremity injuries (Zhang et al., 2011). This concept, however, has not been researched extensively across different types of spring loading compressions. Based on this gap in existing literature, the purpose of this study was to examine the effect of a spring loading cane mechanism on upper and lower extremity ground reaction forces during cane aided walking. The preliminary findings of this research study may have implications for future research on spring loading cane designs and the implementation of rehabilitation protocols for patients and health providers. While conducting this study, it was hypothesized that the use of low compression levels on a spring loading cane mechanism during walking would minimize upper extremity ground reaction forces via the shaft of the cane and would gradually increase ground reaction forces at the simulated injured leg.

METHODS: The research design of this study was a one group cross-sectional design across four different spring cane loading compressions. Before collecting any data for this study, ethical approval was obtained from the Lakehead University ethics board. For this study, 29 healthy participants (13 female and 16 male) with a mean age of 22.6 ±1.9 years completed two testing sessions. This population group was used to gain preliminary information on the effect of a spring loaded cane mechanism on upper and lower extremity ground reaction forces before implementing this approach in older populations. Two sections were needed to minimize the effect of confounding variables that could pose a threat to the internal validity of the data due participants' unfamiliarity with the equipment and testing protocols. During the first testing session, participants were familiarized with the equipment and testing protocol. During the familiarization process, participants were asked to kick a ball to identify their dominant leg and were fitted with a T-Scope© knee brace on their dominant leg. The T-Scope© knee brace was locked and stayed at 30 degrees of knee flexion to simulate a knee injury during testing trials (Butler et al., 2014; Mohammed, 2016). Participants were also fitted with a spring loaded cane with compressions set at 25%, 50%, 75% of the total spring loading compression; 25% was the softest cane compression setting and a rigid setting did not have a spring loading cane mechanism. The spring compression settings for the cane were determined based on the research protocol of Shortell et al. (2001). The spring loaded cane was adjusted to each participant by having them stand and hold the cane perpendicular to the ground with the elbow flexed between 15 to 30 degrees. A 10-inch goniometer was used to measure the elbow flexion angle to fit the spring loaded cane properly to the participants. Participants were asked to perform 10 practice trials with cane-assisted walking by holding the cane contralateral to the simulated injured leg to get familiar with the equipment and testing protocols. This testing session lasted 15 minutes.

During the second testing session, participants were again fitted with the T-Scope© knee brace on their dominant leg and the spring loaded cane contralateral to the simulated injured leg to collect the ground reaction force data. Participants were given 5 minutes to re-familiarize themselves with the spring loaded compression cane device prior to data collection. Once participants were comfortable with the cane-assisted walking protocols, they were instructed to ambulate over two Advanced Mechanical Technologies Incorporated (AMTI) force plates. The first AMTI force platform was used to measure and collect the vertical ground reaction forces generated by the participant's simulated injured leg during walking. The second AMTI platform was used to measure and collect the upper extremity vertical ground reaction forces induced through the spring loaded cane shaft when the bottom tip of the cane contacted the force plate during the walking protocol. A/D Instrument Power Lab Software was used to collect and process the data. Five trials were performed for each spring loading compression. Each trial was performed at a walking speed ranging from 1.25 m/s to 1.50 m/s. These values represented the normal walking speed for this population group. The speed was monitored using two sets of Brower timing gates. One set of the timing gates was used at the start of the walking cycle to activate the timer. Another set was used at the end of the walking cycle to stop the timer as the participant walked over the force plates. The speed was calculated by dividing the walking distance between timing gates over the time. The participants were required to complete five cane-assisted walking trials with the four different types of spring-loaded compressions (25%, 50%, 75%, and rigid), in a non-randomized order. Trials were considered valid when participants hit the force platform with no secondary bounce and were within the time parameter. Participants were required to walk with a continuous stride. An abnormal stride was thought to manifest through a hesitation or break in the natural stride. This testing session lasted approximately 20 minutes per participant and included all trials.

Means and standard deviations were used to tabulate and describe the data. To test the hypothesis, a 2 (upper and lower extremity) x 4 (25%, 50%, 75% and rigid spring loading compressions) mixed factorial ANOVA with repeated measures on the second factor was conducted to examine the interaction effect of these two factors on measures of vertical ground reaction forces. One-way repeated measures ANOVAs and t-tests for independent measures were also conducted to help explain the interaction. Finally, a Bonferroni post hoc analysis was implemented to detect any significant differences on measures of ground reaction forces between mean pairs of spring cane loading compression settings after conducting the one-way repeated measures ANOVAs at $p<0.05$ level.

RESULTS: The results of the mixed factorial ANOVA revealed a significant interaction effect between spring cane loading compressions and extremity on vertical ground reaction forces with a medium effect size, $F(1.68,94.18)=5.56$, $p=0.008$, $\eta 2=0.090$. When explaining the interaction effect between spring loading compression settings and extremity on vertical ground reaction forces, the simple main effect analysis conducted with the one-way repeated measures ANOVA revealed a significant difference on measures of vertical ground reaction forces among the spring loading compressions for the upper extremity, *F(1.47,41.16)=4.16,* $p<.05$, $\eta^2=0.129$. That is, a low spring compression level or less rigid setting seems to generate lower ground reaction forces at the upper extremity via cane shaft. The Bonferroni post hoc analysis demonstrated that the differences were between the 75% (*M* =1.84, *SD*=0.72) and the 50% (*M*=1.69, *SD*=0.70) spring loading compression levels. In the case of the lower extremity, the simple main effect analysis conducted with the one-way repeated measure ANOVA revealed no significant differences on measures of ground reaction forces among the different types of spring loading compressions, *F (1.94, 54.53) = 1.64, p=.204*. The t-test for independent measures, however, revealed significant differences between the upper and lower extremity ground reaction forces with the lower extremity having higher ground reaction forces across spring loading compressions as shown in Table 1. That is, significant differences on measures of ground reactions forces were found for the rigid cane, *t(35.55)=18.39, p=.001;* 75% spring loaded cane, *t(35.10)=18.57, p=.001;* 50% spring loaded cane, *t(34.88)=19.58*, *p=0.001*, and 25% spring loaded cane, *t(35.96)=19.93, p=0.001.*

Table 1: Mean Vertical Ground Reaction Forces and Standard Deviations for Cane Type and Extremity

Cane Type	Extremity	Mean Force(N)	Std. Deviation	Sample Size
Rigid Cane	Leg	9.27	2.03	29
	Arm	1.86	.75	29
Spring Cane 75%	Leg	9.26	2.02	29
	Arm	1.84	.727	29
Spring Cane 50%	Leg	9.37	1.99	29
	Arm	1.69	.70	29
Spring Cane 25%	Leg	9.37	1.95	29
	Arm	1.63	.74	29

DISCUSSION: For this study, it was hypothesized that the use of low compression levels or less rigid setting on a spring loading cane mechanism during walking would minimize upper extremity ground reaction forces via the shaft of the cane and would gradually increase ground reaction forces at the simulated injured leg. When examining the interaction effect between the extremity and spring cane loading compressions on measures of vertical ground reaction forces, the results supported the hypothesis indicating a significant reduction of 12% (comparing a rigid setting to 25% spring compression) in the upper extremity ground reaction forces transferred via the shaft of the cane as the spring compressibility decreased. The outcome, however, did not support the hypothesis on significant increases of ground reaction forces at the lower extremity as the spring compressibility decreased. When comparing the outcome of this study to previous research, the results support the research work of Zhang et al. (2011), who stated that the use of a spring loaded cane may reduce upper extremity ground reaction forces, consequently reducing the risk of injuries at the upper extremity. The interaction effect also revealed significant differences between the upper and lower extremity on measures of ground reactions forces across the spring settings. That is, there was a gradual increase in ground reaction force differences between the lower extremity and upper extremity as the spring cane compressibility diminished. This outcome seems to be supported by the research work of Zhang et al. (2011), which stated that the energy of the impact from cane strike is used to propel the body forward after the mid-stance phase of the walking cycle. Under this premise, it is possible that the energy stored in the spring may increase the vertical ground reaction forces in the injured leg while decreasing ground reaction forces in the upper extremity.

CONCLUSIONS: From the theoretical perspective, the research of the current study supports and builds on existing literature by further exploring the effect of different types of spring cane compressions on upper and lower extremity ground reaction impact forces during ambulation. Although, the outcome of this study did not reveal significant differences for the lower extremity, from the practical perspective, the results seem to offer another avenue to improve the design of spring loaded cane mechanisms for injury prevention at the upper extremity during lower extremity rehabilitation purposes. This outcome may also have implications for patients and health providers regarding the prescription and use of spring loaded canes.

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