

## PERFORMANCE ON AN OBSTACLE COURSE: OTTO BOCK C-LEG VS. OTTO BOCK 3R60 VS. CATECH SNS

<sup>1</sup> Margrit R. Meier, PhD, CPO, Andrew H. Hansen, PhD <sup>1,2</sup>, Steven A. Gard, PhD, <sup>1,2</sup>  
<sup>1</sup> Northwestern University Prosthetics Research Laboratory and Rehabilitation Engineering  
Research Program; <sup>2</sup> VA Chicago Health Care System  
Chicago, Illinois

**Introduction:** The C-leg<sup>®</sup> is considered by many prosthetists and manufacturers to be the leading microprocessor-regulated knee mechanism currently available on the market. What sets it apart from others is its hydraulic knee unit with microprocessor-controlled stance and swing phase damping characteristics that provide monitoring and intervention capabilities during the entire walking cycle.

Previous investigations of microprocessor-controlled knee joints have reported mixed results, ranging from data showing clear benefits for amputees to those that suggest there is no difference at all when compared to conventional knee mechanisms [1-4]. The reported results are not sufficient to objectively determine the benefits of the C-leg<sup>®</sup> as most of the reported studies are related to the Intelligent Prosthesis (IP) by Blatchford. Objective evidence is needed to determine if there is significant benefit when prescribing expensive microprocessor-controlled knee mechanisms over high-performance passive knee units that cost significantly less.

In this short paper the following specific objectives of the study are presented: (1) to determine the participants' walking performance while walking over an obstacle course and (2) to examine the influence of mental loading while walking over the obstacle course with three different knee units.

**Methodology:** *General:* In a crossover study design, each participant wore each prosthetic knee joint—Otto Bock C-leg, Otto Bock 3R60 and Mauch SNS—for a period of four weeks. Test prostheses were fabricated using a duplication of the participant's current prosthetic socket, and each participant was fitted with a Dynamic Plus foot. *Participants:* Persons with unilateral transfemoral amputation, aged between 40 and 60 years, with a body-weight less than 125 kg, were included in the study if they presented with no serious complications that interfered with their walking ability; had six or more months of experience with a definitive prosthesis; were able to walk unassisted at a comfortable speed without undue fatigue and without health risk; and were able to climb stairs. *Protocol:* The obstacle course was set up in the VA Chicago Motion Analysis Research Laboratory (VACMARL). It consisted of foam section (3m long, 1m wide, 20 durometer on a shore A scale), narrow slaloms around three chairs, a vacuumized bean-bag section (3m long, 1m wide) simulating sand, a rock section (3m long, 1m wide), a short downward sloping ramp (1.5m long, 1.4m wide), a 90-degree left turn, and a final stair step (height: 12cm) (Figure 1). The mental loading test consisted of a mathematical calculation task where the participant had to count vocally backwards in 3-step increments (first visit), in 7-step

increments (second visit) and in 3-step increments (third visit). Participants completed the obstacle course twice, once without mental loading, and once with mental loading. No familiarization run was allowed. They were videotaped allowing time to be measured. *Statistical Analysis:* Due to the non-parametric data distribution Friedman Test was used to assess the overall performance of the three knee joints. If a variable reached significant level, Wilcoxon Signed Rank Test was used to test between differences of each knee joint. A Bonferroni correction was applied to account for multiple testing, lowering the significance level to 0.016.

**Results:** Data from 11 participants, two females and nine males, were analyzed. Their mean age was  $45.8 \pm 9.5$  years, mean height was  $175 \pm 9$  cm, and mean weight was  $81.8 \pm 14.1$  kg. They were all established walkers with their amputation having occurred  $20.1 \pm 14.2$  years ago. Seven participants had their amputation due to a traumatic incidence, one due to Peripheral Vascular Disease (PVD), two due to infection and one due to a congenital deficiency. Three out of the 11 participants had a knee-disarticulation amputation.

The median time taken to complete the obstacle course with the 3R60 knee joint was 34.9seconds (s), the minimum time (min.) was 23.9s and the maximum time (max.) was 84s. Adding the mental task altered the time only minimally: 34.2s (min. 22.9s, max. 82s). For the C-leg, the total time was slightly lower when compared to the 3R60 knee joint: median time 32.1s (min. 22.1s, max. 73.1s). By adding the mental task the median time for the C-leg increased to 33.9s (min. 18.1s, max. 69.8s). The difference between the 3R60 knee joint and the C-leg was non-significant for both conditions (without mental task:  $p=0.169$ ; with mental task:  $p=0.045$ ). Participants performed best on the obstacle course when fitted with the SNS unit. Their total median time without mental task was 30.9s (min. 26s, max. 75.2s). Adding the mental task increased the median time slightly to 32s (min. 23.8s, max. 75.2s). The difference between the SNS and the 3R60 knee joint was significant for both conditions (without mental task:  $p=0.011$ ; with mental task:  $p=0.005$ ). However, the difference between the C-leg and the SNS knee joint was non significant (without mental task:  $p=0.674$ ; with mental task  $p=0.678$ ) (Figure 2).

**Discussion:** The participants completed the obstacle course in the shortest time when fitted with the SNS knee joint, followed by the C-leg, and they were slowest with the 3R60 knee joint regardless if a mental task was administered or not. Roughly summarized: the more complex knee joint (3R60) and the more sophisticated knee joint (C-leg) performed less favorable in the given context. It could be that the more complex and sophisticated knee joints require more time and training in order for the user to be able to take full advantage of their characteristics. Thus the given 4-week accommodation period may not have been enough. However, it could also mean that for soft or uneven walking surfaces, a simpler knee joint—represented by the SNS knee joint—simply performs better, as participants have a quicker and direct impact on its behavior.

The mental task had its biggest impact on the C-leg: participants performing with the C-leg reduced their performance speed by 6% compared to their non-mental task performance. The SNS knee joint induced only a 4% speed reduction compared to the non-mental task performance. This may indicate that the microprocessor-driven knee joint did not reduce mental

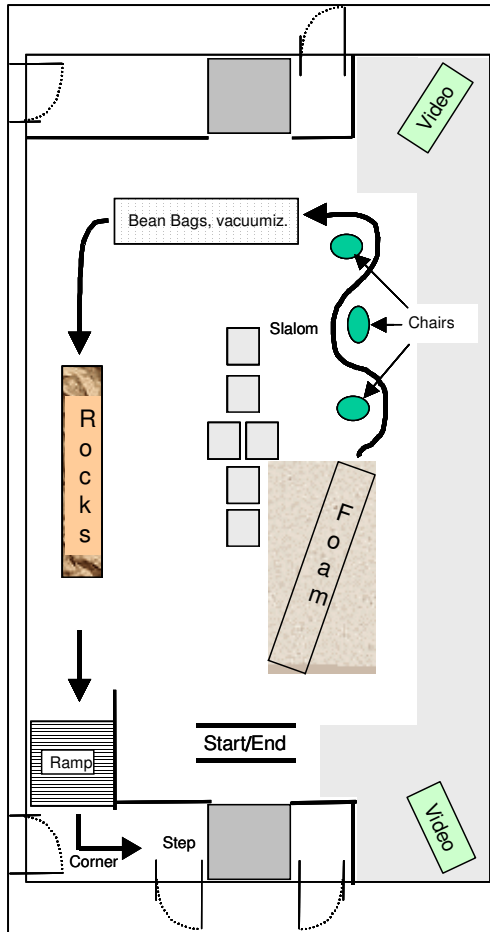
loading during the obstacle performance as anticipated. Participants slowed down more with the C-leg to perform the two tasks simultaneously—walking safely and calculating correctly—than with the SNS unit. In contrast to the two single-axis knee joints, performance with the multi-axis knee joint (3R60) and the mental task enhanced participants' speed slightly by 2%, possibly indicating the influence of the stability provided by the positioning of the knee's instantaneous center of rotation [5]. In-depth detailed analysis may be possible to perform once the aimed sample size of 15 participants has been reached.

**Limitations:** The obstacle course was set up within the gait laboratory and thus represented a controlled environment that may not be representative of outdoor conditions. However, the different walking surfaces and narrow curved pathways demanded higher ambulation skills than walking on the level laboratory surface, thus challenging participants' performances.

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**Figure 1**

Overview of obstacle course set-up within the VACMARL laboratory: Foam Section (3m long), Slalom Section around three chairs, vacuumized Bean Bags to mimic sand (3m long), Rock Section (3m long), Ramp (1.5m long), Corner (90° degree left turn) and a Step (12cm high). Two video cameras were set in such a way that the entire obstacle course could be filmed, allowing time measurements for each section.

**Figure 2**

Total time taken (in sec) to complete the obstacle course for each prosthetic knee joint.  
 w/o MT: without Mental Task  
 \* SNS-3R60:  $p=0.011$   
 w MT: with Mental Task  
 \*\* SNS-3R60:  $p=0.005$

