Friday, May 21st			
Start Time (UTC)	**Finish Time (UTC)**	**Event**	**Presenter**
2:00pm	**2:50pm**	**GPB Podium Session (concurrent)**	
2:00pm		SIMULATING WALKING FOR DEVELOPING METABOLIC ESTIMATION METHODS	Alex Dzewaltowski
2:10pm		3-DIMENSIONAL ANALYSIS OF SELECTED KINETICS AND IMPULSE VARIABLES BETWEEN MIDDLE AND WING VOLLEYBALL ATTACKERS DURING BLOCK JUMP BASED ON INTEGRATION METHOD	Ali Fatahi
2:20pm		OLDER ADULTS COPE WITH COGNITIVE COMPLEXITY WITH GREATER COST TO THE GAIT PERFORMANCE	Hyeon Jung (Judith) Kim
2:30pm		SHOULDER, TORSO, PELVIC COORDINATION PATTERNS IN RUNNERS WITH UNILATERAL LOWER LIMB AMPUTATION	S. Mukui Mutunga
2:40pm		IS THE CLINICIAN BEING LEFT BEHIND IN THE AGE OF ENLIGHTENMENT FOR EXOSKELETON TECHNOLOGY?	Alec Basten

SIMULATING WALKING FOR DEVELOPING METABOLIC ESTIMATION METHODS

Alex Dzewaltowski[1], Seungmoon Song[2], Philippe Malcolm[1]
[1]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE, USA
[2]Department of Mechanical Engineering, Stanford University, Stanford, CA, USA
email: adzewaltowski@unomaha.edu, web: cobre.unomaha.edu
Presentation Preference: [Please indicate (1) **Podium preference, Student**]

INTRODUCTION

Attainable reduction in metabolic rate is one of the main performance indicators for assistive devices, but there are many challenges associated with metabolic cost measurement. While respiratory measurements are the gold standard, their usefulness is greatly diminished by various clinical populations' inability to exercise for sufficient durations to obtain steady-state measurements. In this abstract, we investigate if an existing predictive model can estimate changes in metabolic rate from an assistive device, thereby eliminating the need for exposing clinical populations to strenuous tests.

Our lab has reported reductions in metabolic rate during walking with assistive forces at the center of mass (COM) [1]. Assistance was provided with 35 different force conditions by utilizing a tether connection at the subject's waist. We have applied these experimental force conditions to the COM of a neuromuscular model from Song and Geyer [2,3]. The neuromuscular model utilizes a muscle reflex system coupled with a series of constraints consistent with a human range of motion that is capable of discovering strategies for walking. By combining the muscle behavior predicted by the model with standard equations for estimating the muscle-metabolic cost, we can predict metabolic rate without experimental data input. We hypothesize that the model will independently predict experimentally measured reductions in metabolic rate due to assistance at the COM.

METHODS

Neuromuscular model

Utilizing the algorithm Covariance Matrix Adaptation – Evolution Strategy (CMA-ES) to optimize the model, the optimization process achieves an emergent walking pattern consistent with young and elderly walking depending on the physiological input parameters [3]. By applying our experimental force conditions to this model, we can generate muscle data outputs necessary for metabolic rate estimation. The neuromuscular model was constrained to sagittal plane dynamics. Nine muscle groups were implemented in the analysis: gastrocnemius, soleus, tibialis anterior, glutei, lumped hip flexors, vastii, rectus femoris, biceps femoris (short head), and hamstrings. The model optimization process tunes 71 parameters that are separated into ten modules of control. These modules are split evenly between the stance and swing phase of walking.

Metabolic rate

We have chosen the Umberger et al. (2003) equations for estimating the metabolic rate from muscle actions. Data required for metabolic rate prediction from the neuromuscular model are muscle excitation, activation, fiber length, fiber velocity, and fiber force. Equation 1 consists of the components to approximating metabolic rate as the summation of heat rate ($\dot{h}_A$), maintenance heat rate ($\dot{h}_M$), shortening/lengthening heat rate ($\dot{h}_{SL}$), and the mechanical work rate of the contractile element ($\dot{w}_{CE}$) [4].

$$\dot{E} = \dot{h}_A + \dot{h}_M + \dot{h}_{SL} + \dot{w}_{CE} \qquad \textbf{Eq 1.}$$

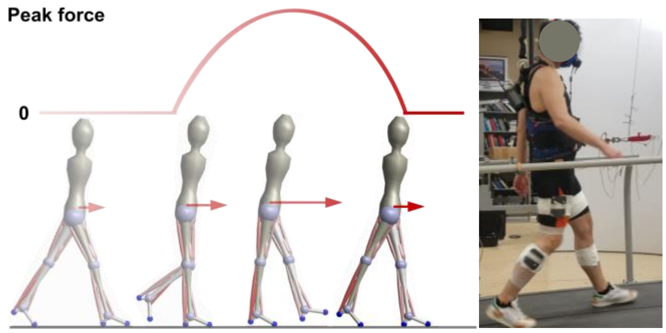

Figure 1: Neuromuscular model and experiment with assistive force at COM

Experimental Comparisons

We implemented the force conditions used in our previous experiment onto the neuromuscular model's COM. Each force condition has a set peak force, onset timing, and duration. Onset timing and duration are continually being adjusted to maintain a set percent of stride. **We predicted reductions in metabolic rate for nine out of twelve conditions that successfully optimized. With an assistive force of 8% body weight, we predicted the reduction of metabolic rate.**

Experiments reduction: 3.43 to 2.57 W/kg (-25.2%)
Model Prediction: 2.69 to 2.00 W/kg (-25.7%)

RESULTS AND DISCUSSION

The model has successfully discovered walking while assisted at the COM. The emergent muscle contraction strategies from the model yielded reductions in metabolic rate similar to experimental data for a single condition. With this initial positive result, we plan to refine the model to better predict a larger number of the experimental conditions in hopes of better replicating overall trends.

CONCLUSIONS

Following further development, this modeling process has a strong potential to produce data not otherwise easily attained for various experiments.

REFERENCES

[1] Prokopios et al. 2021, Under review
[2] Song S. & Geyer H., 2015, *Journal of Physiology*
[3] Song S. & Geyer H., 2018, *Journal of Physiology*
[4] Umberger et al., 2003, *Comp.Methods in Bio & Bio Eng.*

ACKNOWLEDGEMENTS

Original experimental data was collected by Arash M. Gonabadi and Prokopios Antonellis. COBRE P20GM109090

3-Dimensional Analysis of Selected Kinetics and Impulse Variables between Middle and Wing Volleyball Attackers during Block Jump Based on Integration Method

Ali Fatahi[1], Razieh Yousefian Molla[1], Mitra Ameli[2]
[1]Department of Sports Biomechanics, Islamic Azad University of Central Tehran Branch, Tehran, Iran
[2] Department of Sports Science, Payam-e-Noor University of Karaj, Tehran, Iran
Email: fattahiali81@gmail.com

Presentation Preference: [**Podium**]

INTRODUCTION

Within the volleyball game skills, Block and Attack are presenting the highest correlation with success, independent of the game phase [1]. Monitoring block jump actions in middle and wing attackers is crucial to improve performance and avoid injuries during this skill [2], therefore the aim of this study was to investigate the 3-Dimensional analysis of selected kinetics and impulse variables between middle and wing volleyball attackers during block jump based on integration method.

METHODS

21 healthy male junior volleyball players of national team (11 wing attackers and 10 middle attackers) were selected to participate in this study. The athletic task tested was Block Jump that was performed by middle and wing volleyball attackers. Block technique is a vertical jump performed with contribution of Stretch-Shortening cycle. The subject starts from ready position with the hands in front of his chest and fingers extended. It begins with a preliminary downward movement by flexing at the knees and hips (eccentric phase) and then the knees and hips are immediately extended again to jump vertically (concentric phase) while the hands moving upward and totally extended above the head

The 3-Dimentional average, maximum and minimum of GRF (Average Force (X, Y, Z), Maximum Force (X, Y, Z), and Minimum Force (X, Y, Z)) obtained from Force plate system output, and 3-Dimentional impulse (X, Y, Z)) were obtained by integrating force with respect to time. Also, time between two minimum and maximum GRF's peaks (Time between Two Peaks) were calculated for each jumps [3].

Statistical analysis was performed with SPSS Version 21.0 statistic software package. Average Mean and Standard Deviation were used for descriptive analysis. Shapiro-Wilk test was used for normality of data. If so, Independent t-test was performed to compare any differences of variables in three dimension between two attacker's groups during block jump.

RESULTS AND DISCUSSION

The results highlights that middle attackers have greater average force in Anteroposterior (X) and vertical (Z) directions during block jumps, but wing attackers show larger impulse in vertical (Z) direction as well as greater time duration between minimum and maximum force peaks ($p<0.05$).

According to the nature of game's position of these two groups, functional differences may come throughout their performance in Block jump, where middle Blockers generally have more tendency to jump with less knee flexion. Their main role is first blocking the opponent middle attackers and then covering the net against their wing attackers, so their priority is saving time through lesser knee flexion and faster displacement to both side of the net. On the other side, wing attackers during their block performance have enough time to reach to their best performance as they would jump against the opponent wing attackers.

CONCLUSIONS

This study provide new information about monitoring differences between kinetics and impulse of block jumps of volleyball player attackers. The middle attackers showed greater average force in anteroposterior (X) and vertical (Z) directions during block jumps, but wing attackers show larger impulse in vertical (Z) direction and also, time duration between minimum and maximum force peaks. This specific differences in variables of two groups may be useful and physical trainers who will be able to learn that different player' roles require specific jump training loads, and coaches, who will be able to manage task constrains in order to design proper training programs for optimal performance and minimizing related injuries.

REFERENCES

1. Zahálka F, Malý T, Malá L, Ejem M, Zawartka M. Kinematic analysis of volleyball attack in the net center with various types of take-off. *Journal of human kinetics*. 2017; 58(1):261-71.
2. Challoumas D, Artemiou A. Predictors of attack performance in high-level male volleyball players. *International journal of sports physiology and performance*. 2018; 13(9):1230-6.
3. Robertson DGE, Caldwell GE, Hamill J, Kamen G, Whittlesey S. Research methods in biomechanics: Human kinetics; 2013.

ACKNOWLEDGEMENTS

Our authors would like to thank Islamic Republic of Iran Volleyball Federation.

OLDER ADULTS COPE WITH COGNITIVE COMPLEXITY WITH GREATER COST TO THE GAIT PERFORMANCE

Hyeon Jung Kim[1], Farahnaz Fallah Tafti[2], Jennifer M. Yentes[2], Dawn M Venema[3], Julie Blaskewicz. Boron[1]
[1]Department of Gerontology, University of Nebraska at Omaha, Omaha, NE USA
[2]Department of Biomechanics, University of Nebraska at Omaha, Omaha, NE USA
[3]Division of Physical Therapy Education, University of Nebraska Medical Center, Omaha, NE 68198, USA
Email: hyeonjungkim@unomaha.edu Presentation Preference: [**Podium or Poster**]

INTRODUCTION

In daily life, people often concurrently perform several tasks without any difficulties (e.g., walking and talking). When task performance is considered automatic, it needs minimal attention, and it is not affected by other tasks.[1] With aging, challenges in completing multiple tasks at a time become apparent.[2] Although walking and talking is a common multi-tasking, it is considered as a high cognitive load situation (HCLS) with different type of conversation topics and/or walking conditions, leading to increase fall risks.[3] Cognitive complexity has been defined as how people complexly and/or simply think about events. One way in which cognitive complexity can be tested is with different conversation topics that require additional thought and consideration, that is common topics and uncommon topics. Common topics are conversation topics which one could easily engage in such as small talk. On the other hand, uncommon topics were defined as complex conversation topics that require recall and contemplate about specific times, people, and/or emotions. The length of education is an indicator to address cognitive performance (e.g., working memory and processing speed). Therefore, this study investigated whether two load types: 1) single-task (ST) talking or walking only, and 2) HCLS walking while talking on a phone, impacted gait and/or cognitive performance among young, middle-aged, and older adults.

METHODS

Healthy young (n=7; age=23.16±1.96yrs), middle-aged (n=14; age=44.79±7.42yrs), and older (n=15; age=74.47±3.91yrs) adults participated in this study. The participants completed the two randomized load conditions, ST and HCLS, within 15 days of each other. Potential conversation topics were ranked by the participants' interest and highest ranked topics were selected. During the ST visit, subjects completed 1) two 3-minute phone conversations with common or uncommon topics while seated on a chair, and two 3-minute walking only trials, and 2) two 3-minute walking trials. During the HCLS visit, subjects completed two 3-minute walking while talking on the phone trials with common or uncommon conversation topics. During the all walking trials, subjects walked the perimeter of the laboratory at a self-selected pace, walking over a pressure sensor mat (Zeno Walkway; ProtoKinetics, Haverton, PA, USA) with each pass. For walking performance, stride width and speed were selected because these are considered fall risk indicators. Narrower steps and faster speeds were considered better gait. Words greater than six letters and tentative words (e.g., maybe, perhaps, guess) were selected to quantify cognitive performance. Greater usage of words greater than six letters and less usage of tentative words indicate better cognitive complexity. To identify the effect of conversation topic as well as HCLS, between groups for gait and cognitive outcomes controlling for the length of education, two separate 2 × 2 repeated measures ANCOVAs were used. The significance threshold was α=0.05.

RESULTS & DISCUSSION

HCLS indicated wider stride width compared to single task (p=.013; Figure 1). Gait speed was slower under HCLS, demonstrating decreased walking performance when performing a secondary task ($p < .001$; Figure 1). There were no main effects of age nor interactions. For cognitive complexity, words greater than six letters, there was no main effect of HCLS nor conversation topic. However, there was a condition (HCLS) x age interaction for tentative words cognitive complexity (p=.031). According to the results, younger and middle-aged adults used more tentative words during ST compared to HCLS, while older adults used less tentative words, which means older adults enhanced their cognitive complexity during HCLS condition.

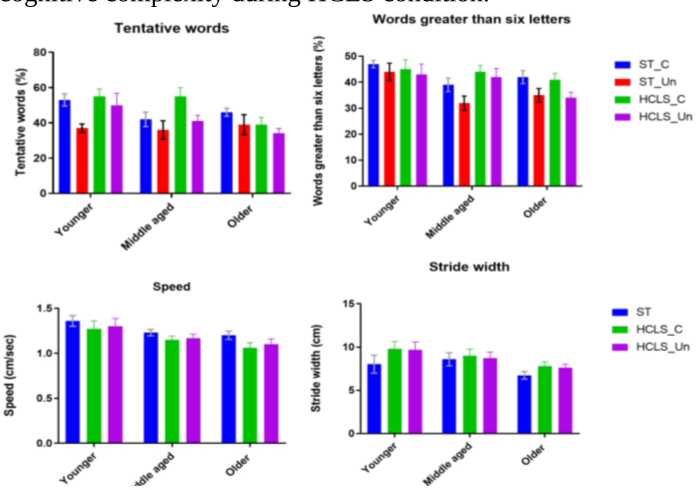

Figure 1: Mean (standard deviation) of single (ST) and HCLS performance Note: Y = young; M = middle-aged; O = older adults; ST = single task; HCLS = high cognitive load situation; C = common topic; UC = common topic; ^ indicates main effect of HCLS

CONCLUSIONS

According to the results older adults prioritized their cognitive complexity over walking during HCLS task condition, which led to decreased waking performance (lower speed and widened stride width), and better cognitive performance. Controlling for the length of education, we did not find any significant different between groups. This may explain that life experience is better resources to recall the past event than the length of education in older adults.

REFERENCES

1. Eichorn, et. al., *J. Speech Lang. Hear. Res*, 2016
2. Wollesen, et al., *Front. Aging Neurosci*, 2019.
3. Farahnaz et al., *Aging Clin Exp Res*, 2020.

ACKNOWLEDGEMENTS

Support provided by University of Nebraska Collaborative Planning Grant and Graduate Research and Creative Activity Fund.

SHOULDER, TORSO, PELVIC COORDINATION PATTERNS IN RUNNERS WITH UNILATERAL LOWER LIMB AMPUTATION

S. Mukui Mutunga[1], Trevor Kingsbury[2], Julianne Stewart[2], Sara E. Wilson[1]
[1]Bioengineering Program, University of Kansas, Lawrence, KS
[2]Naval Medical Center, San Diego, CA
email: mutungam@ku.edu

Presentation Preference: [Podium]

INTRODUCTION

Unilateral trans tibial amputees (UTTAs) present with well documented gait parameter changes and knee and ankle asymmetries on their amputated side when compared to their intact sides. These asymmetries have been known to affect rotations further upstream such as pelvic and hip rotations. These changes in rotations are well documented in UTTAs during walking but not during running [1,3].

METHODS

9 unilateral transtibial amputees (TTAs; 8 - male, 1 - female, average age: 26 y/o, age range: 21 – 41 y/o) with a c-ossur running blade were recruited for this study. Each participant performed 3-6 trials of over ground running on a 9-meter elevated walkway at a self-selected speed (SSS), and at a prescribed speed of 3.5m/s (Jog, range: 3.3 – 3.7 m/s). During these trials kinematic data was collected using a Helen Hayes marker set without head and arm sensors at 300 Hz. Axes were created to track shoulder, torso, pelvic segment rotations for each trial. Coordination patterns of these segments were calculated using Continuous Relative Phase (CRP) [2]. The maximum CRP (CRPmax) angle for each trial was identified as the maximum peak of the CRP curve. Out-of-phase patterns were defined as CRPmax $\geq$ 80°. Matched pairs logistic regression was used to compare intact and amputated side stride CRPmax. CRP variability (CRPvar) was calculated as the side average of the intrasubject stride-to-stride variability. An ANOVA was used to compare intact and amputated side stride CRPvar.

RESULTS AND DISCUSSION

In the jog speed, amputees were 80% more likely to have an out-of-phase torso-shoulder lateral bend rotation on amputated side. This translated to a 14% higher probability out-of-phase coordination pattern on the amputated side when compared to the intact side. In the SSS, the intact side was more likely to have an out-of-phase coordination pattern in pelvis-torso lateral bend and axial rotation. Axial rotation showed a 23% decrease in the probability of an out-of-phase coordination pattern in amputated side-stride when compared to the intact side (Table 1).

ANOVA results for comparisons of CRPvar show statistically significant differences between intact and amputated side stride variability in jog torso-shoulder flexion/extension, and axial rotation, and SSS pelvis-torso axial rotation (Table 2). These results are due to decreased variability on the amputated side.

Table 1: Delta is the differences in probability of amputated and intact sides having an out-of-phase coordination pattern. OR are odds ratios for each rotation.

Rotations	Jog and SSS Matched Pairs Logistic Results			
	Jog Delta (%)	Jog OR	SSS Delta (%)	SSS OR
Torso-Shoulder				
Flex/Ext	-4.80	0.81	6.70	1.30
Lat Bend	14.00	1.80	18.00	2.20
Ax. Rot	-14.00	0.54	-9.80	0.66
Pelvis-Torso				
Flex/Ext	0.00	0.00	0.00.	0.00
Lat Bend	-16.00	0.51	0.58	0.97
Ax. Rot	-22	0.35	-23.00	0.30

Table 2: Jog and SSS ANOVA results

	Jog	SSS
Torso-Shoulder		
Flex/Ext	0.076	0.130
Lat Bend	0.730	0.490
Ax Rot	0.084	0.150
Pelvis-Shoulder		
Flex/Ext	0.330	0.220
Lat Bend	0.950	0.360
Ax Rot	0.220	0.140
Pelvis-Torso		
Flex/Ext	0.430	0.980
Lat Bend	0.310	0.520
Ax Rot	0.150	0.013

CONCLUSIONS

UTTA affects rotations further upstream than expected. Asymmetries commonly seen knee and ankle rotations are also present in shoulder, torso and pelvic coordination patterns when amputated and intact side strides are compared. Less variability in the amputated side stride agrees with results from other studies that have found decreases in variability in populations with low back pain. It is thought that amputees compensate for a lack of musculature in the lower leg by increasing the coupling rotations further upstream. This study shows that these upstream compensations go as far as the shoulders which had not been previously studied.

REFERENCES

1. Burkett, B.; Smeathers, J.; Barker, T. *Prosthet. Orthot. Int.* **2003**, *27* (1), 36–47.
2. Hamill, J.; van Emmerik, R. E. A.; Heiderscheit, B. C.; Li, L. *Clin. Biomech.* **1999**, *14* (5), 297–308.
3. Sanderson, D. J.; Martin, P. E. *Arch. Phys. Med. Rehabil.* **1996**, *77* (12), 1279–1285

ACKNOWLEDGEMENTS

Special thanks to the Naval Medical Center in San Diego for this data and the KU Madison & Lila Self Graduate Fellowship

Is the Clinician Being Left Behind in the Age of Enlightenment for Exoskeleton Technology?

Alec Basten[1], Nicole Walker[2,3] & John M. Looft[3]
[1]Department of Kinesiology, University of Minnesota, Minneapolis, MN USA
[2]Department of Rehabilitation Sciences, University of Minnesota, Minneapolis, MN USA
[3]VA Health Care Systems, Minneapolis, MN USA
email: baste024@umn.edu

Presentation Preference: **Podium**

INTRODUCTION

We are living in the age of enlightenment for exoskeleton technology. A quick search using the term "exoskeleton" in PubMed reveals less than 100 related articles were published in 2010. Since then, the number of related articles has increased exponentially, totaling over 500 articles in 2020. Exoskeleton technology has natural applications within a rehabilitation setting. Rehabilitation exoskeletons allow upright ambulation in populations for which ambulation would otherwise be difficult or impossible. The rehabilitation benefits of upright ambulation in exoskeletons for persons with spinal cord injury (SCI) are immense; notably, improvements in spasticity level, mobility, walking speed, step length and electrical activity at the muscular level have been observed [1].

As exoskeletons are becoming more prevalent in rehabilitation settings, it is increasingly important for clinicians to understand how best to apply them in evidence-based practice. This includes conducting studies using age- and sex-matched healthy controls and looking at clinically relevant measurements such as kinematic (e.g., hip, knee and ankle ROM), spatiotemporal (e.g., walking velocity, cadence, step length, and relative phase), and neuromuscular (e.g., electromyography) gait parameters. Direct comparisons between available exoskeletons are also necessary to provide the scientific basis clinicians need to make confident decisions about when to use one exoskeleton over another. Therefore, the goal of this review is to examine the current breadth of the literature regarding these ambulation parameters for persons with SCI using rehabilitation exoskeletons.

METHODS

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [2], a literature search was conducted across multiple databases (Ovid Medline, PsychInfo, Scopus, Web of Science, and CINAHL). Included literature was published from the inception of the database until June 3rd, 2020. Included literature directly compared exoskeleton gait of patients with SCI and age-matched, healthy controls. Direct comparisons between kinematic gait parameters and/or temporospatial parameters were also necessary for literature inclusion. Excluded literature: (1) Included only healthy participants (2) Included only patients with SCI (3) Did not meet this study's definition of a rehabilitation exoskeleton (a powered, bilateral, lower limb, overground, rehabilitation-focused exoskeleton), and/or (4) Was not reproducible (e.g., methodology was unclear or did not provide specific parameters of the exoskeleton). Only English language literature was considered. Books, book chapters, grey literature, unpublished work, non-peer-reviewed literature, and conference abstracts were also excluded.

RESULTS AND DISCUSSION

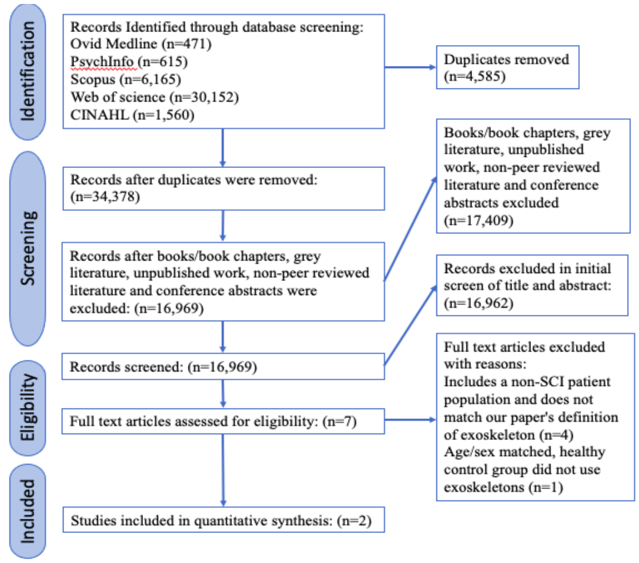

Figure 1: The initial search yielded a total of 38,963 works. After the removal of duplicates, and other ineligible works, seven articles were read in their entirety and thoroughly evaluated against eligibility criteria. Two of the seven passed full text screening and were included in this study.

CONCLUSIONS

Only two out of 38,963 works identified in the search met our inclusion criteria for clinical relevance. No article directly compared two exoskeletons. In the enlightenment age of exoskeletons, much is being done for research and development of the technology, but the specific needs of clinicians who apply it are not being met. The future of exoskeletons for rehabilitation is exciting – we must direct the enthusiasm for this technology towards boosting the clinically relevant evidence base in order to best improve patient outcomes.

REFERENCES

1. Holanda LJ, et al. *Journal of NeuroEngineering and Rehabilitation* **14**, 1-7, 2017.
2. Liberati A, et al. *PLoS Medicine* **6**, 1-28, 2009.

ACKNOWLEDGEMENTS

This project was supported by the University of Minnesota's Office of Undergraduate Research.