RESEARCH ARTICLE

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Pushing A Sled with Constant Resistance and Controlled Cadence Induces Lower Limb Musculature Quicker Activation Response and Prolongs Duration with Faster Speed

Martin Rosario, Collin Pagel, Whitney Miller, and Mark Weber

ABSTRACT

Physical inactivity is rising in both youthful and older people. Such inactivity is problematic for many reasons, primarily because it contributes to overall physical deconditioning. This study examines characteristics in lower extremity muscle adaptations while pushing a sled at constant resistance with three varying cadences. Twenty-one graduate school participants with an average age of 22.8 years consented to place electromyography (EMG) electrodes on their dominant leg. The targeted muscles for the EMG electrodes were over the gastrocnemius (GA), tibialis anterior (TA), and gluteus maximus (GMax). The subject's muscle activation was monitored over three different walking protocols at varying cadences. The protocols were: slow walk (SW, 80 bpm), intermediate walk (IW, 110 bpm), and fast walk cadence (FW, 140 bpm). The investigation results portrayed two main findings: the muscles studied exhibited faster muscle recruitment and a shorter duration of activation when cadence was increased from the IW to the FW cadence. The second discovery among the IW and FW protocols revealed that the GA and Gmax showed greater muscular adaptations than the TA. In conclusion, pushing the sled proves effective in recruiting lower extremity musculature, indicating it could be of great use in rehabilitating individuals deemed deconditioned.

Keywords: Lower extremity muscle variations, Lower limb EMG, Neuromuscular adaptations, Sled, , XPO trainer.

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M. Rosario*
Texas Woman's University, School of Physical Therapy, USA.
(e-mail: mrosario1@twu.edu)

C. Pagel
Texas Woman's University, School of Physical Therapy, USA.
(e-mail: cpagel@twu.edu)

W. Miller
Texas Woman's University, School of Physical Therapy, USA.
(e-mail: wjohnson10@twu.edu)

M. Weber
Texas Woman's University, School of Physical Therapy, USA.
(e-mail: mweber3@twu.edu)

Corresponding Author

I. INTRODUCTION

Due to increased sedentary behaviors at work and in the home over the last few decades, the rate of physical inactivity worldwide has continued to increase (World Health Organization, 2020). The World Health Organization estimated that 28% of adults are physically inactive, while 81% of adolescents are physically inactive (World Health Organization, 2020). The COVID-19 pandemic has also markedly risen the prevalence of physical inactivity, specifically in older adults (Grham *et al*., 2021). Periodic or chronic physical inactivity can be particularly damaging to the health of certain populations, especially those with any underlying comorbidities (Grham *et al*., 2021). The adverse effects of short-term physical inactivity can be reversed in younger people, but not as easily in elderly populations (Bowden Davies, *et al*., 2019). Alarmingly, muscle mass naturally declines by approximately 10% per decade after 50, and the previous inactivity can accelerate such deconditioning (Mitchell, *et al*., 2012). A solution to the problems above is using resistance training (RT) exercises to combat the effects of conditioning (Bowden Davies *et al*., 2019).

Resistance training (RT) is a method of exercise used to improve muscular strength, hypertrophy, endurance, power, balance, and coordination (Rosario *et al*., 2021b). Due to its health benefits, major health organizations currently recommend RT, such as the American College of Sports Medicine and the American Heart Association (Kraemer & Ratamess, 2004). These benefits include increased bone mineral density, lean body mass, muscular strength, insulin sensitivity, and muscular endurance (Kraemer & Ratamess, 2004). In addition, RT also decreases body fat percentage, insulin response to glucose, and rate pressure during submaximal exercise (Williams *et al*., 2007). All of which further outline the importance of RT on our overall health and well-being.

Researchers have extensively investigated RT variables and methods for decades, with recent studies focusing on frequency, timing, and velocity (Borde, Hortobágyi & Granacher., 2015). The individual variables studied (frequency, timing, and velocity) correlate with specific training goals for different populations (Kraemer *et al*., 2017). With the XPO sled trainer—a versatile resistance training device—we

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could allow safer training for different populations because it can easily adjust speed and resistance precisely to the individual's training goals (Kraemer *et al*., 2017).

RT is popular among many athletes and healthy adults with no underlying diseases. However, the limitation with some RT protocols is that they are unsafe to use in other populations with underlying pathologies, such as THR, TKR, or individuals with balance issues, to name a few. Therefore, the current study explores the impact of controlled speed on lower limb muscle activation while pushing a sled at constant resistance with proportional speed. Previous studies investigated the sled's ability to impact neuromuscular activation at different speeds in evidently healthy young adults. Findings suggest a sled is a valuable tool in neuromuscular training and strength and endurance training of lower leg musculature (Rosario, 2020; Rosario *et al*., 2021b).

Based on the above studies, it can be hypothesized that an increase in step cadence and proportion resistance while pushing the sled will cause lower limb distinct musculature adaptations, such as faster muscle recruitment. Thus, identifying which speeds reap the greatest muscle recruitment would be valuable in creating tailored rehabilitation RT protocols.

II. Methods

A. *Ethical Statement*

The Institutional Review Board of Texas Woman's University's T. Boone Pickens Institute of Health Sciences – Dallas Center approved this study procedure (Protocol # 20091). Each participant was educated on the procedures and expectations, their rights, risks, and possible adverse effects during the study. All participants then read and signed an informed consent form.

B. *Research Preparation*

The quasi-experimental study recruited subjects for a single 30-minute session for data collection. They then viewed and signed the informed consent and recorded their leg dominance, heart rate, blood pressure, height, and weight. First, the researchers determined leg dominance by performing a posterior pull test and then assessed which leg they reacted with to compensate for the posterior pull (i.e., when pulled posteriorly from their shoulders bilaterally, if they stepped back with their left leg to prevent falling, then we determined their left leg to be their dominant leg). Next, heart rate and blood pressure were taken via a portable electronic blood pressure monitor. Lastly, height was documented based on a self-report from the participant. Then weight was recorded by having the participant step onto a digital scale with shoes on so that the researcher could record the participant's most recent weight in pounds. The participants were then instructed on their role in the study and their tasks with the sled.

C. *Subjects*

Seven male (33.3%) and fourteen female (66.6%) first-year students were recruited from TWU's College of Physical Therapy via outreach through a mass email to the entire class of first-year PT school students, as well as word of mouth from the researchers to their grad one counterparts in the halls between classes at TWU. Our recruited colleagues were required to push the sled with a constant resistance of 40 feet for six trials without assistance at a predetermined stepping rate. They were also required to have a BMI < 40, a stable cardiopulmonary system (which was assessed with blood pressure and heart rate), no current injuries, and be between 20 and 24 years old. The researchers made their best attempts to recruit equally male and female subjects.

D. *Testing Procedure*

After a brief overview of the study, blood pressure and weight collection, determination of leg dominance, and signing of the informed consent form, the individuals were prepped for the EMG placement over the three studied muscle groups. Neuromuscular timing was collected with Delsys Trigno surface EMG (Delsys Inc., Boston, MA, USA). The subjects had their skin shaved if necessary and then cleaned with an alcohol wipe in the three locations for the electromyography (EMG) surface electrodes to be placed on their dominant legs. EMG electrodes were positioned on the muscle bellies of the participants' tibialis anterior (TA), gluteus maximus (GM), and on the lateral head of the gastrocnemius (GA). The EMG activity of the GM, TA, and GA was collected at 1,000 Hz with the electrodes placed, conforming to a standardized procedure published by Rosario *et al*. (2021b).

1) *Equipment Specifications*

The XPO trainer is the sled used in this study for push protocols. The XPO sled trainer measures 43"H × 43.5"L × 35"W and weighs 60-lbs. Rosario and Mathis (2021) stated that this particular sled has the novelty of adapting resistance to speed. Therefore, if sustained constant, the faster the speed, the more continued resistance the sled delivered to the user (Rosario and Mathis, 2021).

2) Gait Protocol

The cadence of an average person walking is approximately 80-120 steps per minute, while fast walking is considered 120-140 steps per minute (Wang WF *et al.*, 2018). Participants started with their foot on a piece of tape, marking the starting line with the sled in front of them and the line. The gait protocol of this study began with a 40 ft warm-up walk while pushing the sled to allow the subject to adapt to the sled and established cadence provided by a donned metronome. The subjects were instructed to push the sled, with shoulders flexed elbows fully extended for the entirety of each trial. Subjects were also instructed to maintain the specific cadence through the endpoint (thus not slowing down prior to crossing the finish line). Once the individuals completed the "warm-up" walk, they then went through the following three protocols while pushing the sled: the slow walk (SW) (80 bpm), intermediate walk (IW) (110 bpm), and fast walk (FW) protocols (140 bpm). Again, the metronome provided and facilitated the varying cadences. All three protocols were 40 ft in the distance, marked by two orange cones (one at the start and one at the end). Two trials of each gait protocol were completed, with a thirty-second rest break between the trials. EMG data were collected during the totality of the 40 ft walkway for all muscles of interest during all three tasks. It stopped once the participant reached 40 ft, marked by a cone. The investigator then turned off the EMG, and the participant stopped walking. Once the participant completed all six trials, the EMG electrodes were removed, cleaned, and prepped for the next participant.

III. Data Analysis

The EMG activity of the gluteus maximus, tibialis anterior, and gastrocnemius muscles was collected at 1,000 Hz for all tasks and cadence. Neuromuscular timing (seconds) variables for all muscles included the point before muscle activation (onset), at maximal peak activation (Time to Peak-TP), after the activity ended (decay), and the period of muscle activation (duration). The EMG data collection averaged two consecutive activation times for each muscle during all trials and tasks. The present study used SPSS (version 28) with a repeated measure ANOVA analysis to compare the means for neuromuscular-time variables for the 80 bpm, 110 bpm, and 140 bpm cadence while pushing the sled. Due to the repetitive nature of the analysis, we consider a p-value of < 0.01 significant.

IV. Results

Table I presents the demographic traits of the participants. Seven males and fourteen females participated in the study. The average age was 22.8 +/- 1.17 years, with an average weight (lbs) of 153.6 +/- 14.89 and an average height (inches) of 68.6 +/- 3.31.

TABLE I: Demographic Data of All Participants

Characteristics	Study Participants (n) = 21
Age	22.8 +/- 1.17 years
Gender	Male = 7; Female = 14
Height (inches)	M = 68.6 +/- 3.31
Height (inches)	M = 68.6 +/- 3.31
Leg Dominance	12 Left; 9 Right
Blood Pressure	Systolic: 118 +/- 7.07 mm Hg Diastolic: 74 +/- 6.36 mm Hg

Table II depicts the comparisons of neuromuscular activation during walking and pushing the sled at three different speeds (80 bpm, 110 bpm, and 140 bpm). GMAX, GA, and TA showed a significantly ($P < 0.01$) shorter time during onset, decay, and duration when comparing slow walk (80 bpm) with an intermediate walk (110 bpm) and fast walk (140 bpm) speeds. Additionally, all muscles exhibited a faster time to peak ($P < 0.01$) when comparing a slow walk (80 bpm) with an intermediate walk (110 bpm) and fast walk (140 bpm) speeds.

Table III illustrates the comparisons of neuromuscular activation during walking and pushing the sled at intermediate (110 bpm) and fast walking speeds (140 bpm). GMAX and GA showed a significantly ($P < 0.01$) shorter time during onset and decay when comparing intermediate walk (110 bpm) to fast walk (140 bpm) speeds. Additionally, GMAX and GA exhibited a faster time to peak ($P < 0.01$) when comparing intermediate walk (110 bpm) to fast walk (140 bpm) speeds. Finally, the TA muscle only showed a significantly shorter onset of muscle activation ($P < 0.01$) when comparing intermediate walk (110 bpm) to fast walk (140 bpm) speeds.

TABLE II: COMPARISONS OF EMG TIMING (SECONDS) FOR GMAX, GA, AND TA DURING VARIOUS WALKING SPEEDS

	Means and SD	Means and SD	P-value
Glut Max	Onset 80 BPM = 5.001 +/- 0.726	110 BPM = 4.017 +/- 0.496	0.001
		140 BPM = 3.44 +/- 0.451	0.001
	TP 80 BPM = 4.573 +/- 0.639	110 BPM = 3.721 +/- 0.492	0.001
		140 BPM = 3.141 +/- 0.783	0.001
	Decay 80 BPM = 7.023 +/- 1.018	110 BPM = 5.676 +/- 0.725	0.001
		140 BPM = 4.654 +/- 1.107	0.001
	Duration 80 BPM = 2.014 +/- 0.331	110 BPM = 1.659 +/- 0.249	0.05
		140 BPM = 1.212 +/- 0.885	0.001
Gastroc	Onset 80 BPM = 5.233 +/- 0.678	110 BPM = 4.160 +/- 0.472	0.001
		140 BPM = 3.460 +/- 0.533	0.001
	TP 80 BPM = 4.664 +/- 0.681	110 BPM = 3.773 +/- 0.488	0.001
		140 BPM = 3.176 +/- 0.526	0.001
	Decay 80 BPM = 7.349 +/- 0.994	110 BPM = 5.882 +/- 0.686	0.001
		140 BPM = 4.913 +/- 0.781	0.001
	Duration 80 BPM = 2.117 +/- 0.358	110 BPM = 1.722 +/- 0.251	0.01
		140 BPM = 1.452 +/- 0.269	0.01
Tibialis Ant	Onset 80 BPM = 5.029 +/- 0.764	110 BPM = 3.984 +/- 0.541	0.001
		140 BPM = 3.369 +/- 0.539	0.001
	TP 80 BPM = 4.612 +/- 0.704	110 BPM = 3.608 +/- 0.724	0.001
		140 BPM = 3.079 +/- 0.461	0.001
	Decay 80 BPM = 0.469 +/- 0.250	110 BPM = 0.402 +/- 0.355	0.80
		140 BPM = 0.264 +/- 0.092	0.05
	Duration 80 BPM = 4.561 +/- 0.756	110 BPM = 3.582 +/- 0.698	0.001
		140 BPM = 3.105 +/- 0.487	0.001

**BPM = Beats per minute; TP = Time to peak.
A MANOVA was performed during walking and pushing the sled at 80 bpm, comparing 110 bpm and 140 bpm speeds. The significance level was set at $p \leq 0.01$.

TABLE III: COMPARISONS OF EMG TIMING (SECONDS) FOR GMAX, GA, AND TA DURING VARIOUS WALKING SPEEDS

	Means and SD	Means and SD	P-value
Glut Max	Onset 110 BPM = 4.017 +/- 0.496	140 BPM = 3.44 +/- 0.451	0.01
	TP 110 BPM = 3.721 +/- 0.492	140 BPM = 3.141 +/- 0.783	0.01
	Decay 110 BPM = 5.676 +/- 0.725	140 BPM = 4.654 +/- 1.107	0.01
	Duration 110 BPM = 1.659 +/- 0.249	140 BPM = 1.212 +/- 0.885	0.05
Gastroc	Onset 110 BPM = 4.160 +/- 0.472	140 BPM = 3.460 +/- 0.533	0.01
	TP 110 BPM = 3.773 +/- 0.488	140 BPM = 3.176 +/- 0.526	0.01
	Decay 110 BPM = 5.882 +/- 0.686	140 BPM = 4.913 +/- 0.781	0.001
	Duration 110 BPM = 1.722 +/- 0.251	140 BPM = 1.452 +/- 0.269	0.01
Tibialis Ant	**Onset** 110 BPM = 3.984 +/- 0.541	140 BPM = 3.369 +/- 0.539	0.01
	TP 110 BPM = 3.608 +/- 0.724	140 BPM = 3.079 +/- 0.461	0.05
	Decay 110 BPM = 0.402 +/- 0.355	140 BPM = 0.264 +/- 0.092	0.26
	Duration 110 BPM = 3.582 +/- 0.698	140 BPM = 3.105 +/- 0.487	0.05

**BPM = Beats per minute; TP = Time to peak.
A MANOVA was performed during walking and pushing the sled at 110 bpm compared to 140 bpm speed. The significance level was set at $p \leq 0.01$.

V. DISCUSSION

The current study investigated differences in lower limb muscle adaptations in participants pushing a sled at constant resistance with three varying cadences, slow, intermediate, and fast. This research presented two main findings: the muscles studied exhibited faster recruitment with a shorter duration of muscle activation when the cadence was increased to intermediate and fast walk protocols than the slow walk protocol. The second finding showed that GA and GMAX displayed more remarkable adaptations than the TA among the intermediate and fast cadences. Previously, we hypothesized that an increase in step cadence while pushing a sled would cause lower limb musculature adaptations, such as faster muscle recruitment. Based on the outcomes generated by this study, we accepted the established hypothesis.

As mentioned above, the first outcome of this study illustrated that all the muscles examined elicited faster recruitment and shorter duration of muscle activation when increasing the participant's cadence from a slow walk protocol to the intermediate and fast walk protocols. One explanation for these outcomes could be that walking at a faster cadence and pushing against the sled's resistance provokes quicker muscle recruitment in the lower limb musculature. This neuromuscular adaptation could further result from a decrease in double limb support and an increase in single limb support when gait speed is increased, supported and documented by previous research (Murray *et al*., 1984). Previous studies using the XPO sled trainer have shown that muscle activation levels in the proximal lower extremity muscles (GMax, GMed) were significantly greater than in the distal muscles (GA, TA) while pushing the sled (Rosario *et al*., 2021b). Additional resistance from the sled affects specific gait parameters, such as cadence and stride length (Rosario *et al*., 2021b). Pushing while walking the sled causes stride length and step cadence to decrease, ultimately increasing stance time (Hyder, Swank & Rosario, 2019). In the Hyder *et al*.(2019) study, the subjects self-selected their walking speed, slightly different from the current investigation. The subjects were instructed on a specific walking speed they needed to maintain by the researchers. Murtagh *et al*.

(2020) documented a frame of reference for what is considered a typical "walking speed" with apparently healthy adults. Researchers explained that average walking speeds ranged from 1.31 m/s to 1.47 m/s, with an average cadence of 116.65 steps per minute (Murtagh *et al*., 2020). This last remark is important to highlight while using the sled to determine when an individual performs above or below the normative range and thus could tailor their intervention accordingly to achieve the highest rehabilitative gains.

Additionally, early muscle activation was reported in this study during the intermediate and fast walk versus slow walk. Based on the above findings, we suggest a faster cadence to promote strengthening without muscle fatigue (shorter muscle recruitment or duration of activation). On the other hand, a slower cadence while pushing the sled would be recommended to promote muscular endurance (prolonging muscle recruitment or duration of activation). Due to the importance of pushing muscles such as the GA, an earlier onset of muscle activation can be beneficial as a neuromuscular retraining approach for groups undergoing lower limb muscle weakness (Guadagnin *et al*., 2019). One patient group often experiences lower limb muscle weakness and issues with the initiation of gait are the Parkinson's population (Thaut *et al*., 2019). Thus, we infer that individuals with Parkinson's disease could benefit from targeted muscle activation, which involves pushing the sled. Patients with Parkinson's tend to struggle with initiating movements and thus could benefit from the sled, where a controlled cadence results in particular muscle adaptations in the lower extremities that help prevent festinating gait patterns (Osborne *et al*. 2021). Thaut *et al*. (2019) looked into Rhythmic Auditory Stimulation (RAS), which significantly decreased the number of falls and increased gait speed and stride length in individuals with Parkinson's disease. Regarding those above, the metronome used while pushing the sled could also provide an excellent auditory cue for patients with Parkinson's, preventing future falls and allowing them to walk with a more normalized gait pattern.

The second finding of this study illustrated that GA and GMAX had greater adaptations to speed modifications than the TA. This outcome suggests that pushing a resistance sled with proportional resistance causes the plantar flexor muscles to become further involved than dorsiflexor musculature. Thus, patient populations who require increased plantar flexor engagement, such as sprinters, jumpers, and swimmers, might benefit from the sled's constant speed and resistance in their rehabilitation process. A study by Rosario *et al*. (2021b), using the same sled as the current study, portrayed that while pushing a sled at a walking pace, the sled can facilitate prolonged recruitment of other muscles, such as the TA, rather than solely the pushing muscles, such as the GA. Researchers additionally found that pushing the sled at a running pace exhibited a faster time to peak activation (TP) for the TA over a shorter period (duration) compared to the self-selected walking pace (Rosario, 2020; Rosario, *et al*. 2021b). Decreased GA and plantar flexor strength have been shown to correlate with multiple aspects of gait and balance, such as decreased gait speed (Shearin *et al*., 2020). Therefore, the current study argues that the sled could be beneficial in these populations to improve their gait speed safely, as we know from this study that GA activity increases when pushing the sled.

Based on the previous results, we propose the sled be used for resistance exercise training in athletes (specifically swimmers, jumpers, and sprinters) that require increased plantar flexor activation. For example, Matsuura *et al*. (2020) investigated muscle synergies of underwater swimmers. They noted that the ankle joint is maximally in plantar-flexion at the end of the downward kick phase of swimming, with an increase in propulsion (Matsuura *et al*., 2020). Furthermore, the same study also mentioned a co-contraction of the TA and GA, which occurs when kicking and maintaining ankle plantar flexion against the resistance of the water (Matsuura *et al*., 2020). Therefore, targeting the GA via sled training would be beneficial in rehabilitation for the phase above of swimming.

Future studies should include EMG measurements of bilateral lower extremities and trunk musculature to better understand their activation patterns and the adaptations of those muscles to controlled speeds. Prospective research should also investigate other patient populations that may benefit from resistance exercise while pushing a sled with constant speed and resistance, such as older adults or individuals diagnosed with Parkinson's. This previously mentioned concept could be done by incorporating a broader research participant pool to identify muscular adaptations in populations other than relatively healthy young adults between the ages of 21 and 40, as research in the present study. This study could not effectively calculate force and resistance measures produced while pushing the sled due to the lack of recording speed and time variables. Future studies should include these factors in their investigations to collect these essential variables. Additionally, an investigation into pulling a sled with constant resistance may be beneficial in assessing and treating patient populations with anterior musculature and core deficits. Lastly, like Rosario *et al*.'s (2021a) research, we recommend exploring the effects of an extended walkway combined with lactate measurements to assess muscle activation and fatigue adaptations.

VI. CONCLUSION

The current study aimed to explore differences in lower extremity muscle adaptations while pushing a constant resistance, sled at a constant resistance with three varying cadences. While exploring the impact of controlled speed on lower limb muscle activation pushing the sled, we found that GA, TA, and GMAX exhibited faster recruitment with a shorter duration of activation when cadence was increased to intermediate fast walking than slow walking. Additionally, GA and GMAX displayed greater adaptations than the TA among the intermediate and fast cadences. This study ushers in examining lower limb muscle adaptations from constant resistance with three varying cadences. In the future, studies should investigate bilateral lower extremities and trunk musculature adaptations while pushing a constant resistance sled, and studies should begin to investigate these adaptations in older adults and other populations, such as Parkinson's disease, those living with HIV, and people suffering from muscle weakness due to diabetes.

REFERENCES

Borde, R., Hortobágyi, T., Granacher, U. (2015). Dose–response relationships of resistance training in healthy old adults: A systematic review and meta-analysis. *Sports Medicine*, 45(12), 1693-1720. doi:10.1007/s40279-015-0385-9.

Bowden Davies, K.A., Pickles, S., Sprung, V.S., *et al*. (2019). Reduced physical activity in young and older adults: metabolic and musculoskeletal implications. *Therapeutic Advances in Endocrinology and Metabolism*. doi:10.1177/2042018819888824.

Ghram, Amine, Briki, Wali, Hend, Mansoor, Abdulla Saeed Al-Mohannadi, Carl J. Lavie & Karim Chamari. (2021). Home-based exercise can be beneficial for counteracting sedentary behavior and physical inactivity during the COVID-19 pandemic in older adults. *Postgraduate Medicine*, 133(5), 469-480, DOI: 10.1080/00325481.2020.1860394.

Guadagnin, E.C., Priario, L.A.A., Carpes, F.P., Vaz, M.A. (2019). Correlation between lower limb isometric strength and muscle structure with normal and challenged gait performance in older adults. *Gait Posture*, Sep 73, 101-107. doi: 10.1016/j.gaitpost.2019.07.131. Epub 2019 Jul 4. PMID: 31319373.

Hyder, A., Swank, C., & Rosario, M. G. (2019). Pushing a Sled: Assessing its Impact on Gait Temporospatial Parameters in Young Healthy Adults [Texas Woman's University]. *Journal of Student Research*. https://doi.org/10.47611/jsr.vi.673.

Kraemer, William J., *et al*. (2017).Understanding the science of resistance training: An evolutionary perspective. *Sports Medicine*, 47(12), 2415-2435.

Kraemer, W.J., Ratamess, N.A. (2004). Fundamentals of resistance training: progression and exercise prescription. *Med Sci Sport Exerc.*, 36, 674–8.

Martín, G., Rosario, Daniel Heistand, Catie Lewis, Natalie Valdez, Matthew Nevarez, Mark Weber. (2021a). Lower limb muscle activity adjustment and lactate variation in response to increased speed with proportional resistance in young adults. *International Journal of Sports Medicine and Rehabilitation*, 4,18.

Matsuura, Y., Matsunaga, N., Iizuka, S., Akuzawa, H., Kaneoka, K. (2020). Muscle synergy of the underwater undulatory swimming in elite male swimmers. *Frontiers in Sports and Active Living*, 2. doi:10.3389/fspor.2020.00062.

Mitchell, W.K., Williams, J., Atherton, P., Larvin, M., Lund, J., Narici, M. (2012) Sarcopenia, dynapenia, and the impact of advancing age on human skeletal muscle size and strength; a quantitative review. *Front Physiol*., Jul 11(3), 260. doi: 10.3389/fphys.2012.00260. PMID: 22934016; PMCID: PMC3429036.

Murray, M. P., Mollinger, L. A., Gardner, G. M., & Sepic, S. B. (1984). Kinematic and EMG patterns during slow, free, and fast walking. *Journal of Orthopaedic Research*, *2*(3), 272–280. https://doi.org/10.1002/jor.1100020309.

Murtagh, E.M., Mair, J.L., Aguiar, E. *et al*. (2021). Outdoor Walking Speeds of Apparently Healthy Adults: A Systematic Review and Meta-analysis. *Sports Med*, 51, 125–141 https://doi.org/10.1007/s40279-020-01351-3.

Osborne, J. A., Botkin, R., Colon-Semenza, C., DeAngelis, T. R., Gallardo, O. G., Kosakowski, H., Martello, J., Pradhan, S., Rafferty, M., Readinger, J. L., Whitt, A. L., & Ellis, T. D. (2021). Physical therapist management of parkinson disease: A clinical practice guideline from the American Physical Therapy Association. *Physical Therapy*. https://doi.org/10.1093/ptj/pzab302.

World Health Organization. (26 Nov. 2020). *Physical Activity*. www.who.int/news-room/fact-sheets/detail/physical-activity.

Rosario, Martin & Keitel, Kelly & Meyer, Josey. (2021b). Constant resistance during proportional speed provoked higher lower limb proximal musculature recruitment than distal musculature in young healthy adults. *International Journal of Physical Education, Fitness and Sports*, 92-102. DOI: 10.34256/ijpefs21310.

Rosario, M.G., & Mathis, M. (2021). Lower limb muscle activation and kinematics modifications of young healthy adults while pushing a variable resistance sled. *Journal of Human Sport and Exercise*, 16(4), 809-823. https://doi.org/10.14198/jhse.2021.164.06.

Rosario, Martin G. (2020). Neuromuscular timing modification in responses to increased speed and proportional resistance while pushing a sled in young adults. *European Journal of Human Movement*, (44), 50-66. https://doi.org/10.21134/eurjhm.2020.44.544.

Shearin, S. M., Medley, A., Trudelle-Jackson, E., Swank, C., & Querry, R. (2020). Plantar flexor strength, gait speed, and step length change in individuals with Parkinson's disease. *International Journal of Rehabilitation Research*, *44*(1), 82–87. https://doi.org/10.1097/mrr.0000000000000439.

Thaut, M.H., Rice, R.R., Braun Janzen, T., Hurt-Thaut, C.P., McIntosh, G.C. (2019). Rhythmic auditory stimulation for reduction of falls in Parkinson's disease: a randomized controlled study. *Clinical Rehabilitation*, 33(1), 34-43. doi:10.1177/0269215518788615.

Wang, W.F., Lien, W.C., Liu, C.Y., Yang, C.Y. (2018). Study on tripping risks in fast walking through cadence-controlled gait analysis. *Journal of Healthcare Engineering*, Vol. 2018, Article ID 2723178, 11 pages, https://doi.org/10.1155/2018/2723178.

Williams, MA., Haskell, WL., Ades, PA., *et al*. (2007) Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation*, 116(5), 572–84.