Original Article

Lower limb muscle activation and kinematics modifications of young healthy adults while pushing a variable resistance sled

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ABSTRACT

Introduction: The XPO Trainer used in this research is a novel device which provides low rolling resistance at low speeds with an immediate and automatic proportional increase in resistance with increased speed. Purpose: To examine the impact of using the XPO Trainer on gait and neuromuscular activation at low and high speeds in young, seemingly healthy adults. Materials and Methods: This work consisted of 35 healthy adults (age: 24.9 ± 3.2 years, weight: 149.8 ± 8 lbs, height: 66.6 ± 4.4 inches). Each participant wore accelerometers/gyroscopes sensors around each wrist and ankle, chest, and low back and surface electromyography (EMG) electrodes on their dominant leg over the quadriceps (QUAD), hamstring (HAM), anterior tibialis (TA), and gastrocnemius (GA). To initiate the tasks, participants walked then ran 40 feet with and without the XPO Trainer sled. Subjects did a total of 3 trials per tasks (total of 12) with one minute of rest between tasks to reduce fatigue factor. The data from the EMG and Mobility Lab sensors were then processed and compared through the SPSS 24 system for a repeated-measures ANOVA. Results: EMG- The QUAD muscle exhibited a substantial higher muscle activation between walk (45.39 ± 24.43) and walk push (74.40 ± 56.73) tasks. Gait Parameters- There was a significant modification ($p \leq .05$) between the different gait variables and tasks, including cadence, gait speed, stride length and trunk velocity while pushing the sled. Conclusion/Clinical Relevance: With the XPO Trainer being a novel device, it is important to understand how it affects the activation and response for muscles during different activities before using it as a training tool. Understanding the effect this particular sled can provide on the different components of the (temporospatial) gait parameters and muscle activation is valuable for a clinically appropriate application to specific populations.

Keywords: Variable resistance sled; Gait parameters; Muscle activation.

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INTRODUCTION

Resistance exercise (RE), a general term referring to exercise requiring one to exert a force against resistance, has been demonstrated to constitute a superior modality for increasing muscle strength, muscle endurance, power, hypertrophy, and motor performance (Fleck SJ & Kraemer WJ, 1997, Kraemer WJ, Ratamess NA, 2004 and Medicine AcoS, 2009) . Seminal work on RE and muscle fibre adaptations demonstrates several key concepts (Staron RS et al., 1994, Staron RS et al., 1989 & Staron RS, et al., 1995). Heavy RE yields a proportional increase in all intracellular components of all muscle fibre types while increasing oxidative phosphorylation with fibre size gain. Muscle fibre size distributions were different in untrained men and women. For instance, mitochondrial content (number and form) of detrained fibres remains constant, heavier RE increases hypertrophy of all muscle fibre types, whereas light RE results in no significant hypertrophy during short-term RE of 8 weeks.

The health benefits of enhancing muscular fitness are well-established (Williams MA, Haskell WL, Ades PA, 2007). Higher levels of muscle strength are associated with significantly improved cardio-metabolic risk factor profiles, lower risk of all-cause mortality (Gale CR, et al., 2007) fewer cardiovascular disease events (Gale CR, et al., 2007), lower risk of developing functional limitations (Hunter GR, McCarthy JP, Bamman MM, 2004), and nonfatal disease (Hunter GR, McCarthy JP, Bamman MM, 2004). Additionally, regular involvement in resistance training results in improvements in body composition (Hunter GR, McCarthy JP, Bamman MM, 2004), blood glucose levels (Castaneda C, Layne JE, Munoz-Orians L, 2002), insulin sensitivity (Brooks N, et al., 2007), and blood pressure regulation (Collier S, Kanaley J, Carhart R Jr, 2009) are among the benefits of RE. Furthermore, RE promotes muscle strength and mass, which increases bone mass and may serve as a valuable measure to forestall, slow, or even reverse the bone mass loss in people with osteoporosis (Kohrt WM, et al., 2004). Related to mental health benefits, RE is associated with prevention and amelioration depression and anxiety (Cassilhas RC, et al., 2010) and lessen fatigue (Puetz TW., 2006).

RE research is conducted by many exercise scientists, with several studies growing exponentially. Of particular interest are the expansion of RE exercise selection (i.e., body weight, implements, vibration, and kettle-bells) and integration with other variables including sequence, velocity, frequency, and rest intervals (Kraemer, William J., 2017).

Our spotlight is on non-traditional training methods like high-intensity power training and CrossFit. One RE equipment utilized by many trainers and sports settings is the static resistance sled. An increment in gastrocnemius and erector spinae muscle activation, when compared with regular resistance squatting, has shown the benefits of using a static resistance sled for RE (Maddigan M, Button D, Behm D., 2014). Notwithstanding, the benefits of changing the load on a static resistance sled to improve sprint performance has yet to show any conclusive evidence (Pantoia PD, et al., 2018). This study focuses on the XPO Sled Trainer. The XPO sled trainer is a novel device that provides low rolling resistance at low speeds with an immediate and automatic proportional increment in resistance with increased speed. The function and impact of the sled trainer are still to be studied. Therefore, the purpose of this exploratory study is to examine the impact of using the Sled XPO Trainer at low and fast speeds on muscle activity (neuromuscular activation) and kinematics (gait) in young, seemingly healthy adults. For the kinematic variables, we hypothesized that temporal-spatial parameters would decrease with an increase in speed and resistance. Further, related to neuromuscular variables, this study hypothesized an increase in extensor musculature (gastrocnemius/hamstring) and decreased in flexor musculature (tibialis anterior/quadriceps) activation with an increase in speed due to proportional increased in resistance.

METHODS

Ethical statement
The study procedure was approved by the Institutional Review Board of Texas Woman's University Dallas Campus (Protocol A2540313). Each participant read and signed an informed consent form subsequent to being educated on the risks, their rights, and possible discomforts they may encounter while taking part in this study.

Research preparation
Participants took part in a quasi-experimental study design that consisted of 1 session that took 1-1.5 hours. After signing the informed consent, and during the beginning of the session, the participant's information (age, weight, and height) was recorded. Participants were asked simple health questions to ensure adequate qualifications in the study. Once identified as qualifying, they were presented with detailed information about the study's procedures.

Subjects
Thirty-five healthy adult males (7) and females (28) (age: 24.9 ± 3.2 years, weight: 149.8 ± 28.7 lbs, height: 66.6 ± 4.4 inches) from the university and surrounding community volunteered to take part in this pilot study. The participants were required to walk without an assistive device, tolerate standing for at least 30 minutes, able to push a 60-lb sled, had a BMI < 40, and have a stable cardiorespiratory system.

Testing procedure
First, the cardiovascular systems were assessed by measuring blood pressure, heart rate, and oximeter readings to ensure stability to enter the study.

Following consent and assessment, participants were asked to identify their dominant leg and were shaved with a non-electric razor, when applicable, to the areas in which the Electromyography (EMG) (delsys) surface electrodes were placed. The participants had EMG surface electrodes placed by the researcher on the following muscle bellies: Quadriceps (QUAD), Hamstring (HAM), Anterior Tibialis (TA), and Gastrocnemius(GA).

Then measurements of maximal muscle contractions for each muscle group were taken. For the quadriceps, participants sat in a chair with a gait belt around the front legs of the chair. First, the participant placed their leg posterior to the gait belt and held the contraction. Second, for the hamstrings, the chair set up was the same, but the participants placed their leg anterior to the gait belt and pulled backward. Third, for the anterior tibialis, the participant stood supported with a hand on the chair, standing on the heel (toes in the air) of the tested extremity during ankle dorsiflexion. Lastly, the gastrocnemius muscle was tested by having the participant rise (ankle plantarflexion) their heel off the floor and push onto their toes. Each of these four activities was held for 10 seconds and at a maximal contraction force.

Measurement of kinematic data was captured by gyroscope and accelerometers sensors with the Mobility-Lab system. Sensors were placed on the participants in the following locations: right and left dorsum of the wrists, right and left lateral ankles, anterior chest, and posterior lower back. After the above mentioned, the participant started the four trials with and without the XPO Trainer sled.

Gait Protocol: Set up for the trials consisted of two cones placed 40 feet apart. The participants were instructed to walk/run on a flat surface from one cone through the second. The four conditions were walking,

walking, and pushing (WP) the sled, running, and running and pushing (RP) the sled. Each participant was given three trials of each condition. The timer and data collection started at the word go and stopped when the back wheel of the sled reached the last cone.

Figure 1. Sled XPO Trainer with surface EMG electrode placement on Tibialis Anterior, Gastrocnemius, Hamstring and Quadriceps.

Data analysis

EMG data was then placed through a filter, rectified to normalize the maximal voluntary contraction(MVC) data to the muscle activations within the tasks for each participant. The data was processed, then downloaded into spreadsheets. The time for each gait task (in seconds) was normalized to the percentage of the task (0-100%). Afterwards, Investigators identify the highest activation points for each muscle during all trials with the corresponding timing percentage in the gait cycle. An average of each data point was estimated, and the mean maximal activation and timing of the corresponding task were subsequently calculated. The means were then placed into the SPSS Data Analysis 25 system for a repeated-measures ANOVA analysis.

The kinematic data was placed into the SPSS Data Analysis 25 system for repeated measures ANOVA analysis. The mobility lab instrument was ineffective in collecting data during the running task; therefore, no data is reported in this section. For the walk, WP and RP tasks, descriptive Statistics and Pairwise Comparisons were gathered for stride length, stride velocity, cadence, gait cycle time, percentage of double limb support, stance vs. swing phase, range of motion of the shank, and peak trunk and shank velocity.

RESULTS

Neuromuscular data

Tables 1 and 3 show the comparison of muscle activation and timing, respectively, between all tasks. As shown in Table 1, although not significant, there is a higher activation during WP and RP on the QUAD compared to the walking and Running tasks respectively. The remainder of the muscle activation data was comparable among the different tasks ($p > .05$). As shown in Table 3, there are no significant differences ($p > .05$) between maximal muscle activation timing within activities, including walk vs. WP or run versus RP. Tables 2 and 4 are comparing muscle activation and timing, respectively, within each task. As shown in Table 2, there was a significant difference ($p \leq .05$) between the muscle activation of the GA and QUAD during the walking task, with the GA being a significantly higher maximal muscle activation. There were no other significant findings ($p > .05$) between muscles in any other task. As shown in Table 4, with no statistical impact, however, there was a difference between GA and HAM muscle activation timing during walking activity. During the walking activity, maximal muscle activation occurred in the GA muscle earlier than the HAM muscle. Also shown in Table 4, there was a difference in the timing of the TA vs. QUAD, as well as the GA vs. the QUAD. TA and GA activation occurred earlier than the quad activation during the WP task.

Table 1. Comparisons of maximal muscle activation (% of MVC Task) between activities among tasks. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Tibialis Anterior	**Means and SD**	**Means and SD**	**p Value**
	Walk: 67.03 ± 29.8	WP:75.5 ± 15.5	1.00 1.00
	Run: 180.7 ± 102.5	RP:153.4 ± 85.7	1.00 1.00
Gastrocnemius	**Means and SD**	**Means and SD**	**p Value**
	Walk: 77.6 ± 16.4	WP:80.4 ± 18.8	1.00 1.00
	Run: 222.6 ± 113.1	RP:190.3 ± 90.2	1.00 1.00
QUAD	**Means and SD**	**Means and SD**	**p Value**
	Walk: 46.01 ± 25.5	WP:66.9 ± 47.4	1.00 1.00
	Run: 180.9 ± 101.35	RP:200.6 ± 89.8	1.00 1.00
HAM	**Means and SD**	**Means and SD**	**p Value**
	Walk: 59.4 ± 38.3	WP:67.2 ± 45.1	1.00 1.00
	Run: 181.2 ± 105.1	RP:152.1 ± 74.4	1.00 1.00

*Note: TA = Tibialis Anterior Muscle. GA = Gastrocnemius Muscle. QUAD = Quadriceps Muscles. HAM = Hamstring Muscles. p = p-Value. p-Value > .05 is not significant. *p-Value < .05 is significant. S.D. = Standard Deviation. MVC=Maximal Voluntary Contraction.*

Table 2. Comparisons of maximal muscle activation muscles during activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at p ≤ .01.

Walk	**Means and SD**	**Means and SD**	**p Value**
	TA: 67.03 ± 29.8	GA: 77.6 ± 16.4	.64
		HAM: 46.01 ± 25.5	1.00
		QUAD: 59.4 ± 38.3	1.00
	GA: 77.6 ± 16.4	HAM: 59.4 ± 38.3	1.00
		QUAD: 46.01 ± 25.5	*.01
	HAM: 59.4 ± 38.3	QUAD: 46.01 ± 25.5	1.00
WP	**Means and SD**	**Means and SD**	**p Value**
	TA:75.5 ± 15.5	GA :80.4 ± 18.8	1.00
		QUAD :66.9 ± 47.4	1.00
		HAM :67.2 ± 45.1	1.00
	GA :80.4 ± 18.8	QUAD :66.9 ± 47.4	1.00
		HAM :67.2 ± 45.1	1.00
	HAM :67.2 ± 45.1	QUAD :66.9 ± 47.4	1.00
RUN	**Means and SD**	**Means and SD**	**p Value**
	TA: 180.7 ± 102.5	GA: 222.6 ± 113.1	1.00
		QUAD: 180.9 ± 101.35	1.00
		HAM: 181.2 ± 105.1	1.00
	GA: 222.6 ± 113.1	QUAD: 180.9 ± 101.35	1.00
		HAM: 181.2 ± 105.1	1.00
	HAM: 181.2 ± 105.1	QUAD: 180.9 ± 101.35	1.00
RP	**Means and SD**	**Means and SD**	**p Value**
	TA:153.4 ± 85.7	GA :190.3 ± 90.2	1.00
		QUAD :200.6 ± 89.8	1.00
		HAM :152.1 ± 74.4	1.00
	GA :190.3 ± 90.2	QUAD :200.6 ± 89.8	1.00
		HAM :152.1 ± 74.4	1.00
	HAM :152.1 ± 74.4	QUAD :200.6 ± 89.8	1.00

*Note: TA = Tibialis Anterior Muscle. GA = Gastrocnemius Muscle. QUAD = Quadriceps Muscles. HAM = Hamstring Muscles. S.D. = Standard Deviation. p = p-Value. p-Value > .05 is not significant. *p-Value < .05 is significant.*

Table 3. Comparisons of timing (% of Task Time) of muscle activation between activities among tasks. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at p ≤ .01.

Tibialis Anterior	**Means and SD**	**Means and SD**	**p Value**
	Walk: 0.44 ± 0.16	WP:0.44 ± 0.17	1.00
	Run: 0.63 ± 0.21	RP: 0.59 ± 0.17	1.00
Gastrocnemius	**Means and SD**	**Means and SD**	**p Value**
	Walk: 0.33 ± 0.18	WP:0.41 ± 0.11	1.00
	Run: 0.59 ± 0.14	RP: 0.52 ± 0.17	1.00
QUAD	**Means and SD**	**Means and SD**	**p Value**
	Walk: 0.47 ± 0.17	WP:0.54 ± 0.15	1.00
	Run: 0.54 ± 0.22	RP:0.55 ± 0.18	1.00

HAM	Means and SD	Means and SD	p Value
	Walk: 0.44 ± 0.17	WP:0.52 ± 0.17	1.00
	Run: 0.48 ± 0.19	RP:0.45 ± 0.16	1.00

*Note: TA = Tibialis Anterior Muscle. GA = Gastrocnemius Muscle. QUAD = Quadriceps Muscles. HAM = Hamstring Muscles. p = p-Value. S.D. = Standard Deviation. p-Value > .05 is not significant. *p-Value < .05 is significant.*

Table 4. Comparison of timing of maximal muscle activation between muscles during activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at p ≤ .01.

Walk	Means and SD	Means and SD	p Value
	TA: 0.44 ± 0.16	GA: 0.33 ± 0.18	1.00
		HAM: 0.44 ± 0.17	1.00
		QUAD: 0.47 ± 0.17	1.00
	GA: 0.33 ± 0.18	HAM: 0.44 ± 0.17	1.00
		QUAD: 0.47 ± 0.17	1.00
	HAM: 0.44 ± 0.17	QUAD: 0.47 ± 0.17	1.00
WP	**Means and SD**	**Means and SD**	**p Value**
	TA: 0.44 ± 0.17	GA: 0.41 ± 0.11	1.00
		HAM: 0.54 ± 0.15	1.00
		QUAD: 0.54 ± 0.15	1.00
	GA: 0.41 ± 0.11	HAM: 0.54 ± 0.15	1.00
		QUAD: 0.54 ± 0.15	.22
	HAM: 0.54 ± 0.15	QUAD: 0.54 ± 0.15	1.00
RUN	**Means and SD**	**Means and SD**	**p Value**
	TA: 0.63 ± 0.21	GA: 0.59 ± 0.14	1.00
		HAM: 0.48 ± 0.19	1.00
		QUAD: 0.54 ± 0.22	1.00
	GA: 0.59 ± 0.14	HAM: 0.48 ± 0.19	1.00
		QUAD: 0.54 ± 0.22	1.00
	HAM: 0.48 ± 0.19	QUAD: 0.54 ± 0.22	1.00
RP	**Means and SD**	**Means and SD**	**p Value**
	TA: 0.59 ± 0.17	GA: 0.52 ± 0.17	1.00
		QUAD:0.55 ± 0.18	.44
		HAM:0.45 ± 0.16	1.00
	GA: 0.52 ± 0.17	QUAD:0.55 ± 0.18	1.00
		HAM:0.45 ± 0.16	1.00
	HAM:0.45 ± 0.16	QUAD:0.55 ± 0.18	1.00

*Note: TA = Tibialis Anterior Muscle. GA = Gastrocnemius Muscle. QUAD = Quadriceps Muscles. HAM = Hamstring Muscles. S.D. = Standard Deviation. p-Value > .05 is not significant. *p-Value < .05 is significant.*

Gait parameters

As shown in Table 5, there was a significant difference between the stride length between tasks. The WP and RP tasks had a significantly shorter (p ≤ .05) stride length compared to the walking task. Likewise, the RP task had a significantly shorter (p ≤ .05) stride length than WP tasks. There was a significant time reduction (p ≤ .05) between the WP when compared to walk and RP tasks. However, stride velocity walking and RP task is comparable (p > .05).

Table 5. Comparison of stride and velocity between activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Stride Length (meters)	**Means and SD**	**Means and SD**	**p Value**
	Walk: 84.9 ± 3.0	WP:69.2 ± 5.2	*.01
		RP:54.0 ± 7.3	*.01
	WP:69.2 ± 5.2	RP: 0.07 ± 0.1	*.01
Stride Velocity (meters/second)	**Means and SD**	**Means and SD**	**p Value**
	Walk: 77.8 ± 5.1	WP:53.7 ± 7.4	*.01
		RP:80.0 ± 11.2	1.00
	WP:53.7 ± 7.4	RP:80.0 ± 11.2	*.01

*Note: W = Walk. WP = Walk and Push. RP = Run and Push. S.D. = Standard Deviation. ROM=Range of Motion. p-Value > .05 is not significant. *p-Value < .05 is significant.*

As shown in Table 6, the walking task has significantly higher cadence ($p \leq .05$) than the walk and WP tasks. However, the WP was significantly slower cadence compared to RP and the walking tasks. As shown in Table 7, there is a significant difference between the gait cycle times during each task. The RP task has a significantly shorter ($p \leq .05$) gait cycle time compared to the walk and WP task. The WP had a longer gait cycle ($p \leq .05$) gait cycle time compared to the walk and RP task.

Table 6. Comparison of cadence (step/minutes) between activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Cadence	**Means and SD**	**Means and SD**	**p Value**
	Walk: 109.5 ± 6.3	WP:92.4 ± 10.1	*.001
		RP:174.2 ± 17.6	*.001
	WP:92.4 ± 10.1	RP:174.2 ± 17.6	*.001

*Note: W = Walk. WP = Walk and Push. RP = Run and Push. S.D. = Standard Deviation. ROM=Range of Motion. p-Value > .05 is not significant. *p-Value < .05 is significant.*

Table 7. Comparison of gait cycle (seconds) between activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Gait Cycle	**Means and SD**	**Means and SD**	**p Value**
	Walk: 1.1 ± 0.1	WP:1.3 ± 0.2	*.001
		RP:0.8 ± 0.1	*.001
	WP:1.3 ± 0.2	RP:0.8 ± 0.1	*.001

*Note: W = Walk. WP = Walk and Push. RP = Run and Push. S.D. = Standard Deviation. ROM=Range of Motion. p-Value > .05 is not significant. *p-Value < .05 is significant.*

Table 8. Comparison of double limb support (%) between activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Cadence	**Means and SD**	**Means and SD**	**p Value**
	Walk: 24.7 ± 3.9	WP:95.8 ± 11.3	*.001
		RP:15.5 ± 4.5	*.001
	WP:95.8 ± 11.3	RP:15.5 ± 4.5	*.001

*Note: W = Walk. WP = Walk and Push. RP = Run and Push. S.D. = Standard Deviation. ROM=Range of Motion. p-Value > .05 is not significant. *p-Value < .05 is significant.*

The percentage of double limb support (Table 8) was significantly ($p \leq .01$) increased during WP compared to walk and RP tasks. However, RP had a shorter ($p \leq .05$) double limb support percentage compared to walking and RP. Table 9 shows the WP task had a significantly ($p \leq .05$) longer stance and shorter swing phase percentage compared to the walking tasks and RP. Table 10 shows the walking task has a significantly higher ($p \leq .05$) shank range of motion value than the WP and RP. However, when no significant difference ($p > .05$) in the shank range of motion was found when comparing pushing tasks.

Table 9. Comparison of gait cycle percentage: swing and stance phase (%) between activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Swing	Means and SD	Means and SD	p Value
	Walk: 37.5 ± 2.4	WP:34.0 ± 1.9	*.001
		RP:42.3 ± 2.3	*.001
	WP:34.0 ± 1.9	RP:42.3 ± 2.3	*.001
Stance	**Means and SD**	**Means and SD**	**p Value**
	Walk: 62.3 ± 1.9	WP:65.9 ± 1.9	*.001
		RP:57.7 ± 2.3	*.001
	WP:65.9 ± 1.9	RP:57.7 ± 2.3	*.001

*Note: W = Walk. WP = Walk and Push. RP = Run and Push. S.D. = Standard Deviation. ROM=Range of Motion. p-Value > .05 is not significant. *p-Value < .05 is significant.*

Table 10. Shank range of motion (degrees) between activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Range of Motion	Means and SD	Means and SD	P Value
	Walk: 84.2 ± 14.4	WP:62.3 ± 5.4	*.001
		RP:61.0 ± 6.7	*.001
	WP:62.3 ± 5.4	RP:61.0 ± 6.7	.74

*Note: W = Walk. WP = Walk and Push. RP = Run and Push. S.D. = Standard Deviation. ROM = Range of Motion. p-Value > .05 is not significant. *p-Value < .05 is significant.*

Finally, Table 11 shows the velocity of shank and trunk (horizontal and frontal) among the different tasks. The shank and trunk velocity appeared to be faster during RP ($p \leq .05$) compared to the other two tasks. On the other hand, the slower velocity ($p \leq .05$) was exhibited by WP when compared with walking and RP.

Table 11. Comparison of peak trunk and shank velocity (m/s) between activities. Results of repeated measure ANOVA performed comparing walk and WP/RP. Significance level set at $p \leq .01$.

Sagittal Shank	Means and SD	Means and SD	p Value
	Walk: 392.2 ± 32.2	WP:293.3 ± 42.7	*.001
		RP:462.4 ± 60.3	*.001
	WP:293.3 ± 42.7	RP:462.4 ± 60.3	*.001
Horizontal Trunk	**Means and SD**	**Means and SD**	**p Value**
	Walk: 20.6 ± 5.8	WP:14.0 ± 4.6	*.001
		RP:57.9 ± 23.7	*.001
	WP:14.0 ± 4.6	RP:57.9 ± 23.7	*.001
Frontal Trunk	**Means and SD**	**Means and SD**	**p Value**
	Walk: 44.1 ± 10.6	WP: 20.6 ± 6.2	*.001
		RP:94.7 ± 48.1	*.001
	WP: 20.6 ± 6.2	RP:94.7 ± 48.1	*.001

*Note: W = Walk. WP = Walk and Push. RP = Run and Push. S.D. = Standard Deviation. ROM = Range of Motion. p-Value > .05 is not significant. *p-Value < .05 is significant.*

DISCUSSION

The purpose of this exploratory study was to examine the impact of pushing a low-constant resistance sled at selected low and fast speeds on muscle activity and kinematics in young, seemingly healthy adults. These study aims were divided into a neuromuscular and kinematic approach while pushing the sled. The novelty of this device lies in the low rolling resistance at low speeds with an instant and automatic comparative gain in resistance with increased speed.

Neuromuscular Activity: This study hypothesized that an increase in extensor (pushing) musculature (gastrocnemius/hamstring) and decrease in flexor musculature (tibialis anterior/quadriceps) muscles activation would be achieved by an increase in speed due to the proportional increase in resistance (Li, W; et al., 2020). This study selected these specific muscles due to the (QUAD/HAM/TA/GA) importance as a neuromuscular motor control participant during gait (Shumway-Cook, A., & Woollacott, M. H., 2007). The results obtained propose an increased activation of the Quad muscle and timing variability while pushing the sled; however, according to our results, the hypothesized is partially accepted.

The benefits of RE have been studied many times over. These benefits include improved muscle strength and mass, improved bone density (Kohrt WM, et al., 2004), as well as many mental health benefits (Cassilhas RC, et al., 2010). The results obtained propose a significant added benefit to pushing the sled versus walking alone when referring to maximal muscle activation of the quad muscle. These results mentioned above suggest that when training the hip flexors, the WP task is recommended over the walking task alone. However, while the maximal activation of the quad was higher during the WP task, this maximal activation occurred later in the task compared to TA or GA muscles. Therefore, the recommended intervention for targeting a weak quad muscle would be the WP task, because it is the most beneficial activity for training both strength and endurance due to the increased muscle activation as well as the later timing in maximal contraction. Studies showed (Maddigan M, Button D, Behm D., 2014 & Okkonen, O. & Häkkinen, K. 2013) similar activation of the Quads muscle pushing a sled compared to a squat manoeuvre and squat type exercises. In addition, it has been found in multiple studies (Okkonen, O. & Häkkinen, K., 2013 & Fry, A.C., Smith, J.C., & Schilling, B.K., 2003) that performing a squat without proper form can increase stress at the knee joint. Knowing the results of all of these studies, it can be inferred that people with balance difficulties, knee pathologies, or the inability or difficulty with squatting, the sled is recommended for the similar benefits on strengthening the quadriceps muscle. It is essential to understand the benefit of identifying the specific function or target muscle for this particular sled. Normal gait speed is essential for adequate functionality. In people with abnormal gait speed, there is a recommendation to work on strengthening the knee extensor musculature (Teixeira-Samela, L.F., Olney, S.J., Nadeau, S., & Brouwer, B., 1999; Osawa, Y., et al., 2019; Reynaud, V., et al., 2019 & Henderson, R.M., et al., 2017). Therefore, due to the targeted Quad activation while pushing the sled, we proposed utilizing the sled for this objective.

During the WP tasks, muscle activation occurred later or delayed, though not significantly for GA, Quad, and HAM compared to the walking task. From a clinical standpoint, this finding suggests when targeting delayed onset activation of the GA, Quad, or HAM or if endurance is the objective of the intervention, a longer time walking while pushing is required. It is important to point out during the walking activity, maximal muscle activation in the hamstring muscle occurred significantly earlier than the gastrocnemius muscle. This outcome suggests while pushing the sled, the effort or force to push forward might be opposite, increased the time for GA recruitment rather than HAM musculature, which might be beneficial for propulsion during the gait cycle in people with weak GA muscles.

There are reported benefits to running or sprinting exercise. In a study conducted by Pantoia et. al. the benefits of changing the load on a static resistance sled to improve sprint performance has yet to show any conclusive evidence (Pantoia PD, et al., 2018). Regardless, during the RP task in our study, the QUAD showed increased activation over the run task alone; additionally, the TA, GA, and HAM all showed a different adaptation by decreasing activation during the RP task versus the running task. This increase in QUAD activation during the RP task suggests more effort flexing the knee than regular running. Thus, if training the quad muscle, the RP task would be recommended. Further, this study shows that during the WP and RP activities, the maximal muscle activation of the TA occurred earlier, though not significantly, than during the walk or run activities, suggesting that for quicker muscle fatigue or increased muscle activation over time, using a sled could be beneficial.

Early GA muscle activation was reported in this study, though not significantly, during the RP task versus the running task alone. This result suggests that when targeting faster recruitment of the GA muscle, the RP task would be recommended, while the running task alone would be recommended if attempting to decrease GA muscle fatigue. The earlier onset of GA can be utilized as neuromuscular retraining in older adults, according to Guadagnin, EC (2019) et al. study. The authors compare the lower limb muscle activation in young and older adults during several walking tasks. One main finding of this study applicable to ours is the greater activation excited by, the older group of the Plantar Flexor musculature in all gait speeds during the stance phase. This greater activation was attributed to an increased co-activation of this muscular and impaired coordination due to the stiffening of the lower limb soft tissue. Based on our results, this study suggests muscle re-education as a benefit of pushing the sled by provoking an earlier onset of the TA and GA musculature while WP and RP.

Gait Parameters Kinematics: We hypothesized that temporal-spatial parameters would decrease with an increase in speed due to the resistance exerted by the sled. Our finding showed a mixed but somewhat expected outcome; therefore, we partially accepted our hypothesis.

Our first finding showed a significant difference in the stride length and velocities produced when switching between walking, WP, and RP. When the goal of the intervention is decreasing stride length, pushing the sled should be considered. This expected result proposes that during gait training where stride length and velocity is part of the intervention plan, the sled, either walking or running, is recommended. By default, a decrease of the individual's stride length and velocity, gives more time to focus on the motor control of each step and work towards a more symmetrical gait pattern (Shumway-Cook, A., & Woollacott, M. H., 2007).

The second gait parameter finding of this study showed a significant difference in the cadence when comparing the different activities (walking, WP, and RP). While all activities showed a significant difference, running while using the sled demonstrated the most substantial increase in cadence. Knowing that the velocity and cadence of an individual are decreased when adding the sled, it can be interpreted that the total gait cycle time would be increased, which the results in fact showed. The sled is advised to focus on proper gait patterns during walking or running with the advantage of an induce slower speed.

The third finding was the increase in gait cycle percentage during both pushing activities. This is clinically relevant when treating patient populations that have difficulty with maintaining appropriate stance time during the gait cycle. By increasing double limb support and stance, this can help to improve stability and balance. Also, an increase was shown during the stance phases of the gait cycle when the sled was added, which means that participants had an increase in ground contact time and a decrease in swing time. This outcome would be clinically relevant when working with patient populations such as Parkinson's disease (Pistacchi, M., et al., 2017), that prefer to walk with a decreased stance time while adding the stability of double limb support, as previously stated. Since the extremities are spending an increased percentage of the gait cycle while pushing, we can infer an added benefit of strengthening the lower limbs by co-contraction during stance is occurring.

Additionally, it was reported that the velocity of the trunk decreased within the horizontal and frontal planes by adding the sled for the walking task. As a clinician, the addition of the sled could decrease the amount of extra energy spent within these planes. Therefore, the patient or client would be able to focus more energy within the sagittal plane to propel the sled. There have been numerous studies on the benefits of resistive training; some of these benefits include increasing walking speed and stride length in specific populations (Park, B.-S., et al., 2015). While our results show that stride length and cadence were decreased when using the sled, the sled trainer can be used clinically to assist in normalizing gait patterns, which can potentially lead to improvements in overall gait.

CONCLUSION

The outcomes we have obtained support utilizing the Sled XPO trainer as a RE tool that provides gait and neuromuscular advantages, on top of the benefits traditional walking or running would offer. Studies, such as the one of Schoenfeld, BJ et al. (2019), show exercising in a multi-joint area will neglect to target and produce a maximal contraction response on specific musculature compared to individual joint exercise movements; notwithstanding, pushing this sled has been proven to have the specific targeted activation of the QUAD as a benefit. Within the field of physical therapy, populations with different specific needs are treated. Some fatigue faster and need to have maximal muscle activation farther into their workouts, and other populations can gain more benefits from earlier activation. Our findings suggest each muscle is unique as to which push task causes the most increase in muscle activation. Additionally, the use of this XPO sled trainer leads to significant modifications to several temporal-spatial gait parameters. Comprehending the effects that this resistive XPO sled can have on the different components of the gait cycle is beneficial for a clinically appropriate application to specific populations. Future studies should be focused on different populations and pathologies, as well as identifying the benefits of different distance and surfaces.

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception and design.

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DISCLOSURE STATEMENT

Authors report no conflict or competing interest.

ETHICAL APPROVAL

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