A KINETIC ANALYSIS TO POWERISER (AN ENERGY STORAGE AND RETURN SPRING LEAF DEVICE)

Ying-Ki Fung, Tzyy-Yuang Shiang*, and Chen-Fu Huang

Department of Physical Education and *Graduate Institute of Exercise and Sport Science, National Taiwan Normal University, Taipei, Taiwan

The purpose of this study was to explore the efficiency of an Energy Storage and Return (ESAR) spring leaf walking device (Poweriser) during the walking. The result showed that the walking efficiency of poweriser was around 80% contrast to a normal walk during the mid-stance phase. In the meanwhile, the muscle activation mainly occurred in thigh muscle probably resulted from the ankle lock design of poweriser. On the other hand, the study also found that all the participants demonstrated a similar VGRF pattern and relative lower muscle loading on shank muscle during the continuous vertical jump with the poweriser. The present investigators doubted that the efficiency and performance of poweriser was influenced by the stiffness of leaf spring, the type of motion, and participant’s body mass.

KEY WORDS:, poweriser, spring leaf, ESAR, walking efficiency, mid-stance

INTRODUCTION:

The Energy Storage and Return (ESAR) spring leaf design have been widely applied to the manufacture of prosthesis for almost 20 years. The benefits of these ESAR spring leaf design was temporal release of energy storage to reinforce the walking performance (Hafner, Sanders, Czerniecki, and Fergason, 2002). However, the efficiency of the ESAR spring leaf prosthesis has been argued for a long time. Gailey (2002) indicated that the supreme spring efficiency for one of the tested ESAR prosthesis was 82% and 241% for the human foot. But an inverted investigation by IAAF (2008) demonstrated an independent scientific report from the German Sport University showed that the famous amputee runner “Oscar Pistorius” got more than 30% mechanical advantage comparing to someone not using the spring leaf prosthesis. All in all, no matter the pervious studies concluded but the importance to conduct the investigation on spring leaf was undeniable; hence, to clarify the past research, the present study utilized a spring leaf walking device “Poweriser” (Böck, 2004) (Figure 1) to explore the effect upon the walking efficiency of mid-stance phase.

METHODS:

Four male collegians (age 26±1 yr, height 170±2 cm, mass without poweriser 65±3 kg and with poweriser 69.2±3 kg) were selected as subjects for this study. They all had the experience in using the poweriser to perform running and jumping.

During the test, subjects were requested to perform the walking with their self selected walking speed and the third step (Right foot) should be onto the force plate; In addition, subjects were also requested to perform 5 continuous vertical jump on the ground level (only the third to the fifth jump would be used to analyze). Both walking and continuous vertical jump were under two conditions: with and without the poweriser, for three trials per each condition (Table 1); moreover only the trial without rocking and stable would be used to analyze.

RESULTS:

The ground reaction force illustrated the efficiency of mid-stance phase between two walking conditions. The result showed that the passive (initial contact phase) and active (propulsion phase) mean peak VGRF for the normal walk were 665.76N and 650.67N respectively (Figure 2). However, there were 769.67N and 619.36N for the poweriser walk respectively (Figure 3). Therefore, the efficiency of VGRFs were 97.73% and 80.47% generated during the propulsion phase contrast to initial contact for the normal and poweriser walk respectively.

Table 1 Experimental design

	Conditions			
	Normal		Poweriser	
	Walk	Vertical Jump	Walk	Vertical Jump
No. of trials	x 3	x3	x3	x3

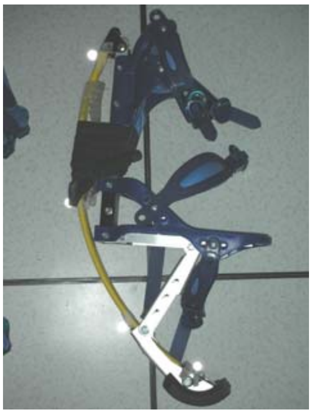

Figure 1: Poweriser equipped with a spring leaf. The aim of poweriser was to facilitate a person to walk or jumping

Likewise, the result also showed that the mean peak HGRF of braking phase and propulsion phase on normal walk were -56.5N and 69.41N respectively (Figure 2). However, there were -108.56N and 91.67N for the poweriser walk respectively (Figure 3). Therefore, the ratio of mean peak HGRF of braking phase and propulsion phase were 1:1.23 for normal walk and 1:0.84 for the poweriser walk.

On the other hand, the ipsilateral corresponding muscle excitation patterns revealed that the thigh and calf muscles exhibited a distinct functional difference between poweriser walk and normal walk. The RF provided a long and continuous firing on poweriser walk (Figure 3: RF, 0-79.75% mid-stance phase) relative to normal walk (Figure 2: RF, 0-35.05% and 83.2-100% mid-stance phase). Inversely, the GAS provided a relative short and intermittent firing on poweriser walk (Figure 3: GAS, 0-20.67% and 66.34-83.8% mid-stance phase) relative to normal walk (Figure 2: GAS, 0-76.72% mid-stance phase).

In present study, the contact phase of vertical jump was also used to illustrate the characteristic between two conditions. The result showed that there was a significant variation between all subjects to perform the vertical jump from 0 to 65% of contact phase (Figure 4). However, all the subjects performed a similar and smooth inverted–U shape pattern with the poweriser (Figure 5). Furthermore, all the tested muscles were firing up to 80% of contact phase for the normal jump during the contact phase (Figure 4). Nevertheless, the muscle excitation patterns were discrete for the poweriser jump (Figure 5).

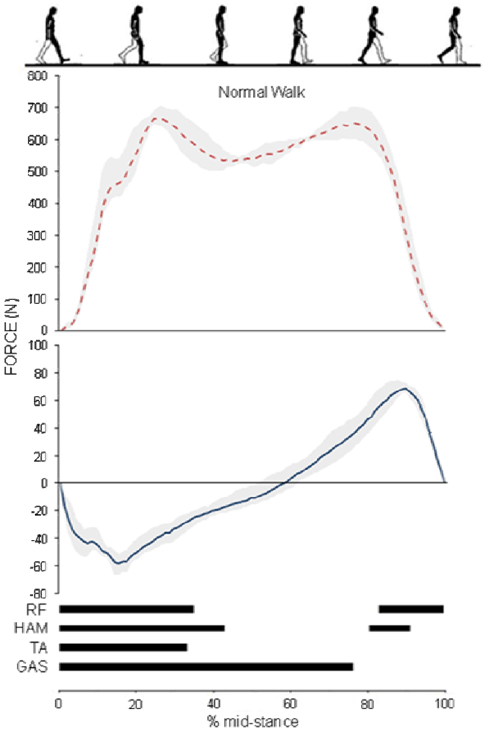

Figure 2 Selected normal VGRF (dot line) and HGRF (solid line) over the mid-stance phase and the black bar indicates the muscle excitation timing. Shaded region indicates the VGRF and HGRF variation among all the participants.

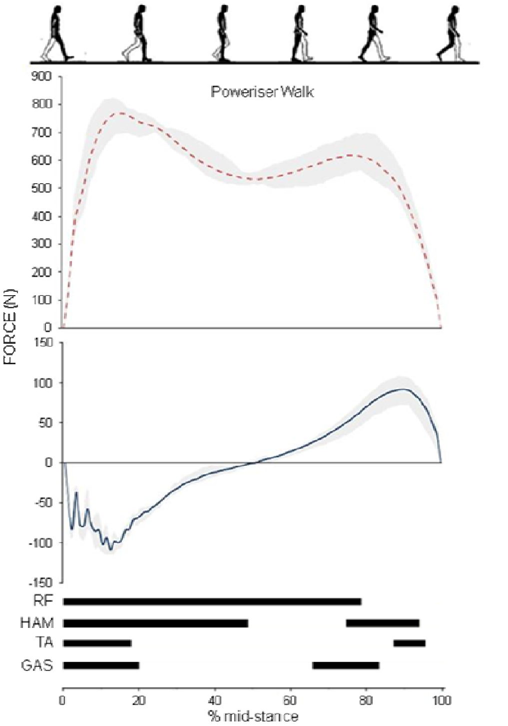

Figure 3 Selected poweriser VGRF (dot line) and HGRF (solid line) over the mid-stance phase and the black bar indicates the muscle excitation timing. Shaded region indicates the VGRF and HGRF variation among all the participants.

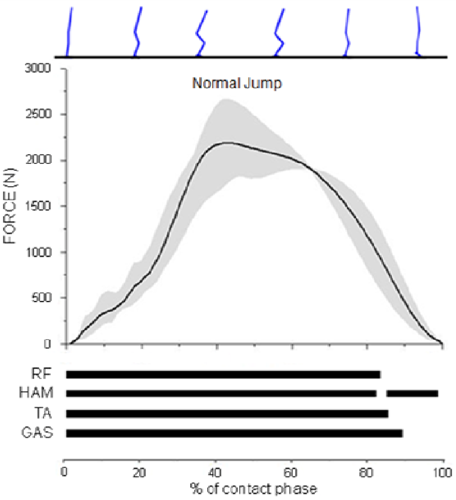

Figure 4. Selected normal VGRF (solid line) over the contact phase and the black bar indicates the muscle excitation timing. Shaded region indicates the VGRF variation among all the participants.

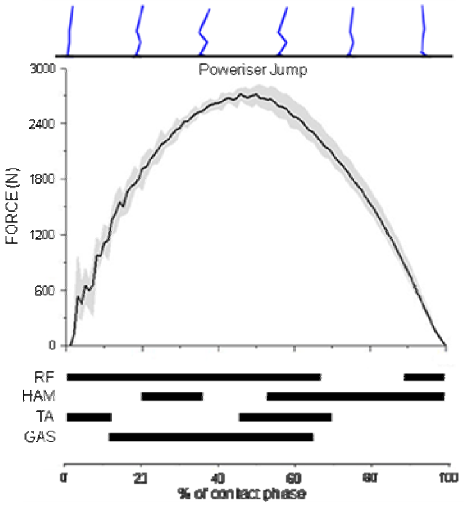

Figure 5. Selected poweriser VGRF (solid line) over the contact phase and the black bar indicates the muscle excitation timing. Shaded region indicates the VGRF variation among all the participants.

DISCUSSION:

Although the present investigator haven't found a relevant study about the ratio between the peak VGRF and HGRF during the initial contact and propulsion phase, however, Wernick and Volpe (2006) showed there were approximately the same or a little bit higher in propulsion phase contrast to the initial contact during walking (first peak = second peak or first peak < second peak), which consisted with this study on normal walk. Nevertheless, the inverse result was found on poweriser walk in present investigation. We believe this discovery may result from the leaf spring structure providing shock absorption during the initial contact phase but it cannot provide an active plantar flexion during the propulsion phase and the rebound energy arising from the leaf spring might depend on the body weight and stiffness. Besides, the resemble studies for the elastic response leaf spring prosthetic have indicated that stiffness properties of leaf spring and speed may affected the efficiency during walking (Geil, 2001; Collins, 2005). Thus, the present investigators believed that the efficiency of poweriser can be increased when suitable stiffness level of leaf spring is adopted and under the running condition. In addition, since the poweriser was an ankle locked structure, the thigh muscles (RF and HAM) played important roles contrasting with calf muscles during poweriser walk. Hence, the results of muscle excitation pattern between normal and poweriser walk (Figure 2 and 3) were predictable.

In previous section, the vertical jump results indicated that the entire poweriser jump pattern (Figure 5) was astonishingly resembled to each other, hence, our speculation about the VGRF was inferred by the stiffness of the poweriser and participant's body weight, for the stiffness of poweriser was the same and all the participants in the test have similar body weight (±3 kg among the participants). Nevertheless, VGRF may be interferred by different preference jumping styles and the muscle power for a normal jump (Figure 4). As a result, there was a significant variation between different participants during the normal jump. The results of muscle excitation pattern on normal and poweriser jump (Figure 4 and 5) showed that the time of muscle activation of normal jump was continuous and longer than poweriser during the contact phase. The present investigators suspected that the muscle of lower extremity played as a force absorber during the normal jump, but for the poweriser condition, the force absorber was born by the leaf spring.

CONCLUSION:

The invention of poweriser was for helping a person to walk (Böck, 2004). However, the present study showed that the efficient of poweriser walk was lower than a normal walk. The present investigators doubted that the efficiency and performance of poweriser were influenced by the stiffness of leaf spring, the type of motion, and participant's body mass. This assumption might also be found in the results of vertical jump. Eventually, it seems that poweriser might lower the shank muscle loading in both walking and vertical jump comparing to the normal condition. However, some limitations arose due to the difficulty on the experimental control (e.g. speed – the incapability to collect the GRF on the treadmill); hence, we suggest that the further study should focus on the influence and optimal stiffness to the poweriser under different intensity and walking / running speed so as to have more comprehensive understanding in the application of ESAR spring leaf device.

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