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GROUND REACTION FORCE OF STEP MARCHING: A PILOT STUDY

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ABSTRACT: Step marching is the rhythmic movement of the lower extremities which combines hip, knee, and ankle joint movements. The rhythmic movement requires standing on one leg involving the voluntary action of moving the center of mass over the upcoming stance leg. Step marching has been used for body balance training methods among the elderly because it is relatively simple and safe amid practice. The amount and direction of ground reaction force during step marching affecting standing balance has not been thoroughly explored. The objective of this study then, was to compare the effect of two different types of marching (comfortable marching and marching incorporating 90-degree hip and knee flexion) walking on vertical ground reaction force (VGRF). Ten healthy subjects (5 males and 5 females) aged 27.6±3.9 years (mean ± SD) participated. Each subject underwent testing with step marching under the two conditions for 2 minutes, and 10 rounds of preferred-speed walking on 2 force platforms. VGRF was measured with Smart analyzer®, BTS Bioengineering software. Paired t-test revealed significant differences in VGRF among the two conditions of step marching and walking whereby step marching incorporating 90-degree hip and knee flexion showed the highest mean value (11.23±0.5 N/kg), whereas the walking condition showed the lowest (10.09±0.6 N/kg). Two types of step marching provide slightly higher VGRF than walking. Hence, they could be applied as a challenge amid balance training among the elderly in case of weight bearing on the bones and joints is required for progressive strength training of the lower limbs.

Keywords: Marching, Walking, Vertical ground reaction force, Healthy

1. INTRODUCTION

Step marching is the rhythmic movement of the lower extremities requiring hip, knee, and ankle joint movement. This movement requires 2 main movements where one leg stands and the other raises from the ground. While standing on one leg, the center of mass of the body is adjusted by the voluntary action of the upcoming stance and standing leg [1]. Dingenen investigated muscle activation amid the double leg stance to single leg stance. The results revealed that the lower limb muscles, namely the Vastus lateralis, Tibialis anterior, Peroneus, Vastus medialis, Tensor fasciae latae, Hamstring, Gluteus medius, and Gastrocnemius were activated [2]. Similarly, Iverson indicated the performance of single leg standing in relation to the torques of the hip flexors, extensors, and abductor [3].

While performing step marching, vertical ground reaction delivers force to the feet into 3 directions i.e. vertical, antero-posterior and medio-lateral [4,5]. Among these, vertical ground reaction force (VGRF) has been known to be the most prominent. Wu and Gu revealed that while standing on one leg, foot and vertical ground reaction force exhibits a relationship with the constant change of weight bearing [6]. In addition, this action challenges the balance system to sustain the body segment within the base of support which can activate body segment acceleration to correct the posture [6,7]. Step marching has previously been applied as a simple field test for assessment of aerobic endurance among the elderly. Moreover, it has been frequently used as a balance exercise to reduce falls in the elderly [8-10]. Ground reaction forces can play a role in challenging body balance control by sending shock waves through receptors from the lower extremities to the central nervous system [11]. Moreover, ground reaction force in other conditions such as fast walking, jogging and running are 1.15-2.45 BW which could be harmful to the joints of the elderly due to the high speed of movement and body weight forces [12].

The ground reaction force of step marching has been investigated in the military field. Carden and colleagues studied ground reaction force in 24 trained soldiers and 12 untrained civilians in performed marching and five drill maneuvers on 2 separated foot force platforms. They found aground reaction force marching range between 1.1-1.3 N/BW [13]. Nevertheless, the amount and direction of ground reaction force during step marching - which may positively affect standing balance - has not been thoroughly explored. Thus, the objective of this study was to compare the effects of two different types of marching (comfortable marching and marching incorporating 90-degree hip and knee flexion) with walking on vertical ground reaction force.

2. METHODS

2.1 Design and Setting

A quasi-experimental study was conducted at a laboratory of the College of sports science, Mahidol University, Thailand.

2.2 Participants

Ten healthy subjects (5 males and 5 females), exhibiting age, weight, height and body mass index of (Mean±Standard deviation) 27.6±3.9, 67.6±12.2, 170.6±8.7, and 23.1±2.5 respectively participated in the study. Prior to intervention outset, subjects were interviewed for their demographic data and any physical issues by the researcher. Eligible subjects were included in the study following inclusion and exclusion criteria as follows: having no pain in the lower limb extremities greater than three weeks before the experiment, no limit of range of motion of the hip and knee joints, and no underlying diseases or abnormalities of the lower limb joints.

2.3 Instrumentation

Before starting the intervention, subjects donned a comfortable shirt and shorts in order to avoid any uncomfortable movement. They were instructed to sit on a chair for 5 minutes and asked if they were experiencing any signs and symptoms such as dizziness or vertigo.

Then, the researcher instructed an intervention procedure which included 3 trials of comfortable step marching, marching at a 90-degree angle, and walking (Figs.4-6).

Vertical ground reaction force data was collected via Klister force plate with a sampling rate of 100 hertz (Klister9260AA3; Klister Group, Winterthur, Switzerland) (Fig.1). The force plate was mounted on top of the existing floor with raised flooring built up around the platform (Fig.2). Vertical ground reaction force data was generated from Smart analyzer®, BTS Bioengineering software (BTS Bioengineering, Milan, Italy) (Fig.2). Additional study equipment included a stopwatch, rope and tripods.

Fig.1 Force platform (Klister 9260AA3; Klister Group, Winterthur, Switzerland)

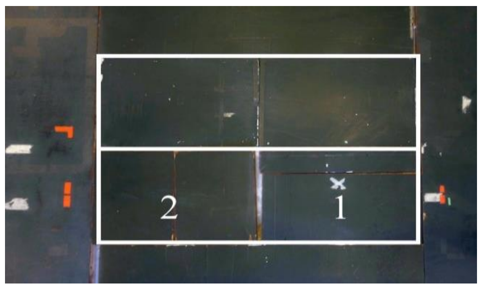

Fig.2 Two Force platforms mounted on the floor

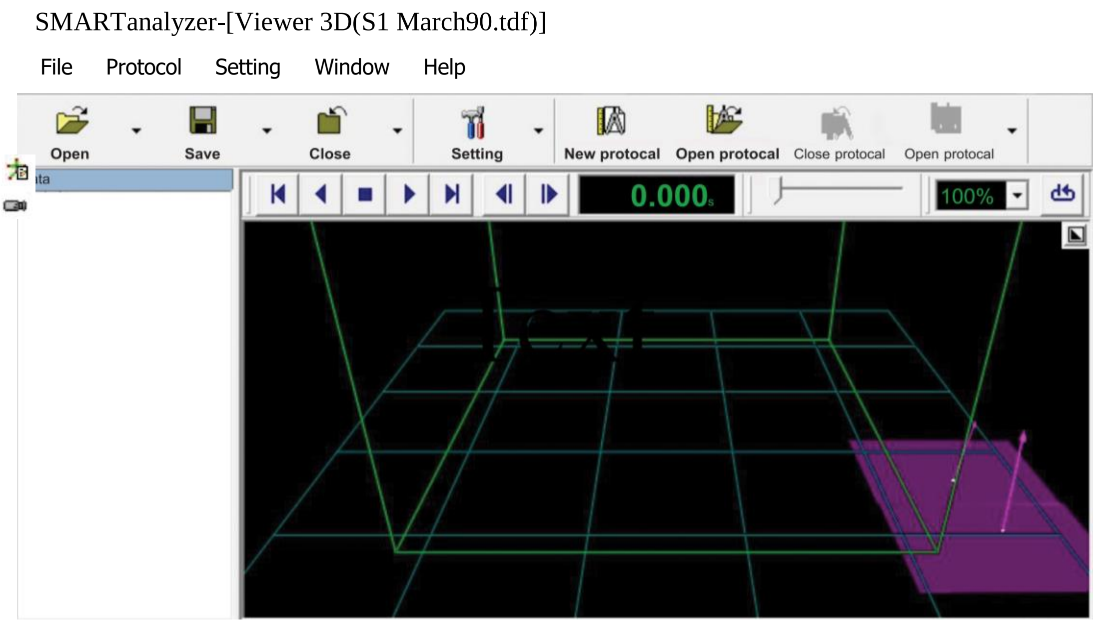

Fig.3 Smart analyzer®, BTS Bioengineering software

2.4 Intervention

For the comfortable step marching trial (Fig.4) participants flexed their hip and knee joints at a comfortable speed and raised the knee to the middle of the thigh for 2 minutes.

The researcher measured individuals' thigh length and prepared a reference rope that instructed participants to reach a specified height level while marching. Marching at 90-degree trial (Fig.5) saw participants flex the hip and knee joints at 90 degrees for 2 minutes. For the walking trial (Fig.6) subjects were instructed to walk barefoot at their preferred walking speed over 10 rounds on 2 force plates. Subjects were instructed to walk placing the side of the foot on the first force plate followed by the second force plate.

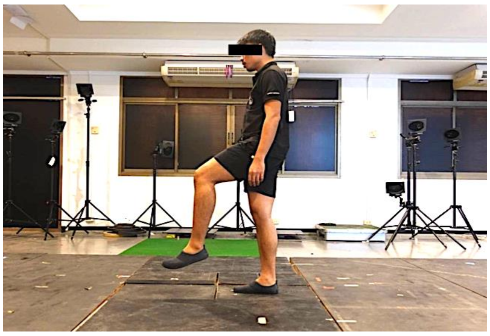

Fig.4 Comfortable step marching trial

Fig.5 90-degree step marching trial

Fig.6 Walking trial

2.5 Statistical Analyses

Descriptive statistics were used to describe baseline demographics and study findings. Shapiro-wilk test was used to ensure normal distribution of vertical ground reaction force (VGRF) data. Paired t-test was employed to determine differences in average vertical ground reaction force within groups. P-value was set at less than 0.05 to define significant differences within groups.

3. RESULTS

All 10 subjects (5 males and 5 females) participated in the study. Inviduals were aged between 26.9±4.1 (Mean ± SD years). Subjects' demographic data are show in Table 1. Paired t-test revealed no significant difference in VGRF (N/Kg) between right and left sides while marching at 90 degrees (M90_Rt and M90_Lt), step marching (CSM_Rt and CSM_Lt), and walking (W_Rt and W_Lt). All data variables are shown as normal distribution as demonstrated in Table 2.

Table 1 Demographic data of ten subjects

Characteristic	Mean ± SD (n=10)
Age (years)	26.9±4.1
Height (cm.)	170.6±8.7
Weight (kg.)	67.6±12.2
BMI (Kg/m^2)	23.1 ± 2.5

Table 2 VGRF comparison between right and left sides

Variables	VGRF (N/Kg)	*p*-value
M90_Rt	11.25±0.52	0.764
M90_Lt	11.23±0.54	
CSM_Rt	10.37±0.43	0.343
CSM_Lt	10.43±0.51	
W_Rt	10.13±0.84	0.678
W_Lt	10.09±0.62	

Note: Mean±SD, Paired t-test., p-value<0.05

Abbreviations: M90_Rt and M90_Lt:VGRF of marching at 90 degrees on the right and left sides. CSM_Rt and CSM_Lt:VGRF of comfortable step marching on the right and left sides. W_Rt and W_Lt:VGRF walking on right and left sides.

Table 3 Comparison of VGRF amid 3 conditions on the right side

Variables	VGRF (N/Kg)	*p*-value
M90_Rt	11.25±0.52	<0.001*
CSM_Rt	10.37±0.43	
M90_Rt	11.25±0.52	0.004*
W_Rt	10.13±0.84	
CSM_Rt	10.37±0.43	0.438
W_Rt	10.13±0.84	

Note: *= Significant difference (p-value<0.05)

Abbreviations: M90_Rt and M90_Lt:VGRF of Marching at 90 degrees on right and left sides. CSM_Rt and CSM_Lt:VGRF of comfortable step marching on right and left sides. W_Rt and W_Lt:VGRF walking on right and left sides.

According to no difference between VGRF on the left and right sides, the researcher selected VGRF of the right side as a reference VGRF value. Step marching incorporates marching at 90 degrees, comfortable step marching, and walking. Significant differences on comparing the conditions were discovered. Differences between step marching conditions are shown in Table 3. Significantly, the results demonstrated that VGRF of marching at 90 degrees was the greatest when compared to other conditions. Nevertheless, no significant difference was found between comfortable step marching and walking condition. Vertical ground reaction force pattern (N) from one participantwas selected to be shown in table 4.

Table 4 VGRF average of bodyweight percentages amid 3 conditions from right and left sides.

Variables	VGRF (%BW)
M90_Rt	1.25±0.07
M90_Lt	1.15±0.06
CSM_Rt	1.06±0.04
CSM_Lt	1.06±0.05
W_Rt	1.03±0.09
W_Lt	1.03±0.06

Abbreviation: %BW = bodyweight percentage. M90_Rt and M90_Lt refer to VGRF amid marching at 90 degrees at the right and left sides, CSM_Rt and CSM_Lt indicate VGRF of comfortable step marching at the right and left sides, W_Rt and W_Lt indicate VGRF walking on the right and left sides.

Table 4 shows mean and standard deviation of VGRF in 3 conditions. These graphs exhibit bodyweight percentage with a different time in second units of time. VGRF graphs in three conditions are shown in Fig.6-8. Hence, they consist of VGRF pertaining to 90-degree step marching condition (Fig.6), VGRF of comfortable step marching condition (Fig.7) and VGRF of walking condition (Fig.8). These graphs represent vertical ground reaction force in newton units (Y-axis) with a difference of time in second units of time (X-axis).

4. DISCUSSION

The objective of this study was to compare the effects of three different types of step marching namely, 90-degree step marching condition,

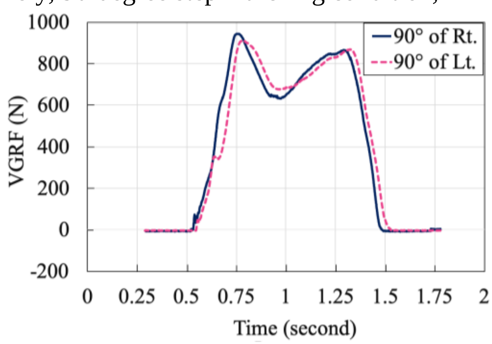

Fig.6 VGRF of marching at 90 degrees trial from right side (90° _Rt.) and left side (90°_Lt.).

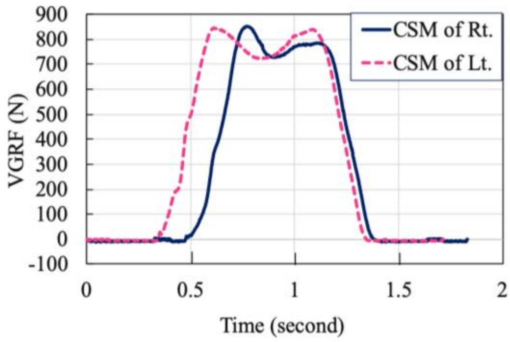

Fig.7 VGRF of comfortable step marching trial from right side (CSM_Rt) and left side (CSM_Lt).

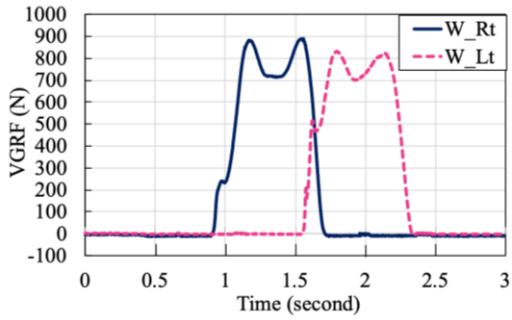

Fig.8 VGRF of walking trial from right side (W_Rt) and left side (W_Lt).

comfortable step marching condition, and walking condition on vertical ground reaction force (VGRF). The results showed that an average VGRF of marching at 90 degrees was significantly highest when compared with comfortable step marching and walking conditions. However, no significant difference was found between comfortable step marching and other conditions.

Factors influencing VGRF include body mass and acceleration. Previous research has investigated VGRF and running speed. They revealed that movement speed was one factor that could increase VGRF [12]. In 90 degree step marching, subjects moved their knee and hip joints to reach the movement target. Although, they needed to push their legs down harder, higher and faster against the force plate when compared to other conditions. In reference to a similar average VGRF between comfortable step marching and walking, these 2 trials seem to call for equal speed and acceleration to achieve the movement.

The results demonstrated that while marching VGRF approximately occurred at between 1-1.2 percent bodyweight in female and male young adults, and per 1 percent bodyweight on walking. Similar to a previous study, Carden and colleagues found that marching exhibited average VGRF between 1.1-1.2 percent bodyweight in trained male and female soldiers, yet VGRF increased to 1.3 percent bodyweight in untrained adult males [13]. However, subjects in this study had no marching experience before participating in the study. Consequently, in this study, it seemed that experience did not affect VGRF.

Hamill and colleagues examined VGRF on running and walking conditions. They revealed that walking at a speed of 1.36 m/s-1 caused an average VGRF of 7.78 N/kg [14]. Moreover, a previous study demonstrated that maximum VGRF also gradually increased for each 1.15-2.45 and 1.23-2.38 of percent bodyweight percentage in females and males, respectively when speed was also increased from 1.5-6.0 m/s-1 [12].

A previous study investigated the effect of walking and sports injuries in the elderly. They discovered in 50 elderly persons who partook in walking training at a moderate intensity certain individuals suffered resultant of training. Fourteen percent of participants were injured from walking on their lower leg, foot, and groin [15]. Thiamwong and colleagues revealed that a simple balance exercise method which included step marching could improve balance in the elderly [9]. Furthermore, the results indicated that marching exercise seemed to produce less of an impact force than jogging which did not induce physical activity injuries in the elderly - especially in running. Although, step marching could have a possible benefit amid its conduction as an exercise for the elderly to enhance muscle activation that aims to produce health benefits in this population.

There were four limitations in the study. Firstly, the researcher did not use a metronome to control the speed of marching in both conditions. Secondly, the researcher did not control the movement of the upper extremities while marching. Thirdly, this study should increase the number of subjects to confirm the effect of marching on VGRF. Fourthly, future studies should increase sample size and control the speed of step marching.

5. CONCLUSION

The objective of this study was to compare the effect of two different types of marching with walking on average VGRF. VGRF outcomes were collected from a force plate and computed via software. Marching at 90 degrees produced a higher average VGRF as opposed to comfortable step marching and walking conditions. Interestingly, the similarity of average VGRF between comfortable step marching and walking may lead to the conducting of marching (1-1.2 BW) as an exercise for the elderly which should not induce physical activity injuries which may occur in jogging and running (1.5-2.45 BW)

7. ACKNOWLEDGEMENTS

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