GROUND REACTION FORCES OF STEP EXERCISE DEPENDING ON STEP FREQUENCY AND BENCH HEIGHT

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Step exercise is one of the most famous Fitness activities. Different music speeds and bench heights can be used in Step classes. During the step cycle the higher mechanical load is experienced when the first foot steps down. The purpose of this study was to determine the ground reaction forces (GRF) of the step-down phase, depending on step frequency and bench height. Two groups of subjects participated in this study: a) 20 female subjects, mean age of 25 years, skilled in Step exercise; and b) 15 female subjects, post menopause, mean age of 62 years. Kistler force plate signals were collected. Increasing step frequency and bench height leads to the increase of mechanical load, which appears trigger adaptations of the movement technique.

KEY WORDS: ground reaction forces, step, step frequency, bench height.

INTRODUCTION: *Step* exercise is one of the most famous *Fitness* activities. It consists of several "steps" (stepping up and stepping down a bench) performed in choreographies. Different music speeds and different bench heights can be used in *Step* classes, as well as different steps. These factors are the most important determinants of exercise intensity. Concerning its characteristics, *Step* exercise can provide a healthy mechanical stimulus, if it is safely performed and prescribed. The mechanical load associated to the body movement produces a ground reaction force (GRF), which can be measured by a force plate. These forces, expressed in units of body weight (BW), indicate the mechanical load produced by an exercise, which can easily be compared to basic locomotion exercises such as walking and running. Newton and Humphries (1991) estimated the values of 1,75 BW for stationary walking and 3,07 BW for stationary running. Baptista (1999) refers that exercises providing mechanical load around 2 BW can be associated to positive osteogenic stimulus. Heinonen *et al* (1999) refer that the maintenance and increase of bone mass were related to unsupervised *Step* exercise and *Aerobics*, associated to 2 – 4,5 BW as osteogenic stimulus. Increased GRF probably are related to greater adaptations of the musculo-skeletal system, concerning muscle activation, segment position, and angular displacement of joints, in order to transfer resultant forces. Motor control also allows the body preparation before contact, increasing muscle preactivation. Data related to these variables was already presented (Franco *et al*, 2000; Santos *et al*, 2000; Santos-Rocha *et al*, 2001 & 2001a). The 4 music counts cycle of the *basic step* with "right lead leg" consists of: 1st – step up with right leg; 2nd - step up with left leg; 3rd – step down with right leg; and 4th – step down with left leg. During the step cycle of *Step* exercise, the highest mechanical load is experienced when the first foot is stepping down (Reebok University, 1994; Hecko & Finch, 1996). So, this study focuses on this phase of the cycle. The purpose of this study was to analyse the influence of step frequency and bench height, on ground reaction forces (GRF), related to the step down phase of one of the most used movement patterns – *basic step*. The step down phase is the period defined from the instant when the 1st foot touches the floor, to the instant were maximal reaction force is obtained. Another purpose was to evaluate the GRF in post menopause elderly women, and compare the results obtained on our studies with those from other authors.

METHODS: Two groups of subjects participated in this study. Group A were 20 female subjects, mean age of 25 ± 6 years, mean weight of 53,5 ± 5,1 Kg, and mean height of 162,1 ± 6,6 cm, skilled in *Step* exercise. Group B were 15 female subjects, post-menopause, mean age of 61,7 ± 5,1 years, mean weight of 66 ± 6 Kg, and mean height of 154 ± 6 cm, who attended supervised *Step* classes three times/week, following ACSM guidelines for exercise prescription (ACSM, 2000).

Group A performed several *basic steps* at 122, 130 and 138 bpm (*beats per minute* – refers to music speed), on a 15 cm *Step Reebok* bench. They also performed several *basic steps* at 122 bpm, on three different *Step* bench heights: 10, 15 and 20 cm. Force plate (*Kistler*) signals were collected and analysed using *Biopac, Inc.* software (*Acknowledge*). In figure 1, one of the subjects is over the force plate and prepares for data collection. Concerning GRF values, the differences between the three conditions of step frequency were tested using ANOVA for repeated measures and the non-parametric test of Friedman (using *SPSS 10.0.*). The same process was used to study the differences between the three conditions of bench height. Group B performed the *basic step* at 120 bpm, on a *Step Reebok* bench of 15 cm high. Force plate (*Kistler*) signals were collected and analysed using *Acknowledge*.

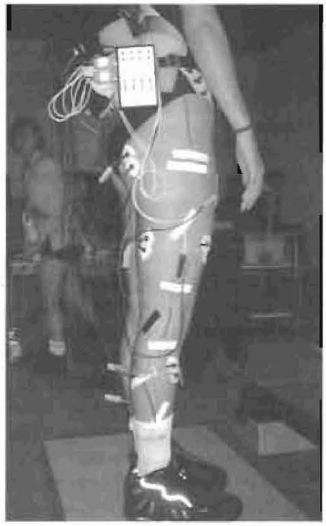

Figure 1. One of the subjects is over the force plate and prepares for data collection.

RESULTS AND DISCUSSION: Concerning the three different conditions of step frequency studied (122, 130 and 138 bpm), the increase of step frequency was related to: the significantly increase of GRF (p=0,000) and the decrease of time interval (DT) values (p=0,000). The mean values found are presented in table 1.

Table 1. GRF and DT values found in the 3 conditions of step frequency (122, 130 and 138 bpm).

	122 bpm*	**130 bpm****	**138 bpm*****
GRF	1,662 BW	1,707 BW	1,769 BW
DT	188 ms	179 ms	171 ms

*Basic step performed at 122 bpm, on a 15 cm bench;
**Basic step performed at 130 bpm, on a 15 cm bench;
***Basic step performed at 138 bpm, on a 15 cm bench.

As seen in table 1, the increase of step frequency leads to the decrease of DT, which is related to the increase of BW (R^2 of 0,407; 0,512; and 0,432 for each condition), and means an increase in mechanical load. Our data showed that the main system adaptation was the increase in knee amplitude during the step down phase, allowing the subjects to cope partially with the increase of mechanical load. Concerning the three conditions of bench height studied (10, 15 and 20 cm), the increase of bench height was related to: the significantly increase of GRF (p=0,000) and decrease of DT values (p=0,000). The mean values found are presented in table 2.

Table 2. GRF and DT values found in the 3 conditions of bench height (10, 15 and 20 cm).

	10 cm*	**15 cm****	**20 cm*****
GRF	1,573 BW	1,662 BW	1,750 BW
DT	203 ms	188 ms	170 ms

*Basic step performed on a 10 cm bench, at 122 bpm;
**Basic step performed on a 15 cm bench, at 122 bpm;
***Basic step performed on a 20 cm bench, at 122 bpm.

As seen in table three, the increase of bench height leads to the decrease of DT, which is related to the increase of BW, especially in 15 and 20 cm (R^2 of 0,186; 0,407; and 0,509 for each condition); this means an increase in mechanical load. Our data showed that the main system adaptation was the decrease in knee amplitude during the step down phase, allowing the subjects to cope with the increase of mechanical load. The women of the post-menopause group (group B), performed the *basic step* movements at 120 bpm, on a *Step Reebok* bench of 15 cm high. The GRF mean value found was: 1.709 ± 0.197 BW. As general discussion concerning health bone, the values for GRF we found are all close to 2 BW, which seem to demonstrate that this physical activity induces to osteogenic process. Nevertheless, these results associated with adaptation observed in knee amplitude, reinforce the idea that the increase either of step frequency or bench height, is related to the general increase of mechanical load. Despite the fact that there is no significant alteration in ankle amplitude because of the muscle activation. This fact is shown by the GRF increase, which could be even greater if the subjects were not able to actively absorb, by the increasing muscle activation, a substantial portion of this load. These results allow us to come to the conclusion that the increase, either of step frequency or bench height, has a consequence on the increase of both external and internal (muscle-tendon) forces (figure 2).

<table>
<tr><td colspan="2">Increase of Step Frequency
Increase of Bench Height
⇓</td></tr>
<tr><td colspan="2">Increase of Mechanical Load</td></tr>
<tr><td>⇓</td><td>⇓</td></tr>
<tr><td>↑ Internal Forces

↑ Knee Amplitude
↑ Muscle Activation</td><td>↑ External Forces

↑ GRF</td></tr>
</table>

Figure 2. Scheme of the influence of step frequency and bench height on the increase of mechanical load.

In table 3 we present the obtained values related to step frequency and bench height, as well as the comparison to other studies.

Table 3. Ground Reaction Forces (in BW) estimated for step down phase of Step exercise under different conditions.

Bench Height	Step Frequency	GRF	Authors
10 cm	122 bpm	1.57 BW	Santos-Rocha; Veloso; Franco & Pezarat-Correia (2001)
15 cm	120 bpm	1.60 BW	Bezner; Chinworth; Drewlinger; Kern; Rast; Robinson & Wilkerson (1996)
20 cm	120 bpm	1.66 BW	Bezner; Chinworth; Drewlinger; Kern; Rast; Robinson & Wilkerson (1996)
15 cm	122 bpm	1.66 BW	Santos-Rocha; Veloso; Franco & Pezarat-Correia (2001)
15 cm	120 bpm	1.71 BW*	Alcoforado-Santos & Veloso (2002)
15 cm	130 bpm	1.71 BW	Santos-Rocha; Veloso; Franco & Pezarat-Correia (2001)
20 cm	122 bpm	1.75 BW	Santos-Rocha; Veloso; Franco & Pezarat-Correia (2001)
25 cm	120 bpm	1.76 BW	Bezner; Chinworth; Drewlinger; Kern; Rast; Robinson & Wilkerson (1996)
15 cm	138 bpm	1.77 BW	Santos-Rocha; Veloso; Franco & Pezarat-Correia (2001)
25 cm	120 bpm	1.83 BW	Reebok University (1994)
20,3 cm	100 bpm	1.90 BW	Hecko & Finch (1996)
20 cm	120 bpm	2.24 BW	Newton & Humphries (1991)
25 cm	120 bpm	2.43 BW	Newton & Humphries (1991)
30 cm	120 bpm	2.9 BW	Newton & Humphries (1991)

*Post-menopause women.

It is important to notice that all the subjects of the present study were familiarly to *Step* classes, and many of them were *Step* instructors. Consequently, the number of *basic steps* performed for data collection of the present study (no more than 20 times) would not lead to fatigue. However, during a *Step* class (lasting 30 to 45 minutes) many steps are performed (about 915 steps during a 30' class at 122 bpm, and 1440 steps during a 45' class at 128 bpm), this means that there could be some changes in GRF regarding the degree of fatigue. The changes in GRF regarding the degree of fatigue might be one of our future concerns.

CONCLUSION: Considering *Step* exercise, one of the main purposes of the present study was to estimate the GRF produced under different performance conditions (and age). As general conclusion concerning health bone, the values for GRF we found are all close to 2 BW, which seem to demonstrate that this physical activity induces to osteogenic process. Concerning *Step* exercise, increasing the step frequency and/or bench height, leads to the increase in mechanical load, which appears to be supported by adaptations of the movement technique. In other terms, *Step* exercise can provide a healthy mechanical stimulus, if safely performed, once its mechanical load is located between the amount of load provided by walk and run. However, if technique adaptations occur, especially on knee joint, together with greater ground reaction forces and decreased time for contact and force transfer, step frequency and bench height (the most important determinants of exercise intensity) should carefully be chosen in *Step* classes, bearing in mind the participants experience in this activity.

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