PEAK GROUND REACTION FORCES DURING STEP AEROBICS, WALKING AND JOGGING

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Step aerobics has emerged as a popular form of exercise being offered in a number of health and fitness centers throughout the world. The step workout involves stepping up and down off a 0.15 to 0.30 meter high box to music. The stepping can include a wide variation of leg and arm movements. Since the introduction of the step workout some participants and instructors have expressed concern about the impacts involved in stepping and the possibility of injury. The peak vertical ground reaction force (GRF) during foot landing has been noted by Nigg, Denoth and Neukomm (1981) as a possible cause of soft tissue and bone injury. Scott and Winter (1990) have determined that peak loads at chronic running injury sites are related to the combination of GRF and the active muscle forces. During running the peak vertical GRF has been measured by Frederick and Hagy (1986) to be 2.86 times body weight (BW) for subjects running at 16 kilometers per hour (kph) and Mero, Komi, Rusko and Hirvonen (1987) found peak vertical GRF of 3.7 BW to 4.8 BW at maximum running speeds.

Francis, Francis, Miller & Hurst (1990) present data on the GRF in the vertical direction during stepping on and off a 0.25 meter platform at a cadence of 120 steps per minute (spm). These forces were compared with running across the forceplate at 11.2 kph and walking at 4.8 kph. The study reported peak vertical forces of approximately 1.75 BW for stepping, 1.25 BW for walking and 3.0 BW for running. It was concluded that the vertical GRF during stepping was only slightly higher than that of walking and both activities were considerably less stressful than running. A thorough evaluation of impact forces during landing has been published by Dufek and Bates (1990) which emphasizes the importance of a toe-heel foot plant and increased knee flexion as movement techniques to decrease impact forces.

The objective of this study was to compare the peak ground reaction forces during walking, running and step aerobics using bench heights of 0.20, 0.25 and 0.30 meters. The effect of increasing bench height on impact force was also assessed.

METHODOLOGY

SUBJECTS

The subjects involved in the study were ten Sport Science students, five female and five male, with mean weight, height and age (+ SD) of 69.9±11.9 kg, 172.0±7.0 cm

and 24.1±5.9 yrs respectively. Although all subjects were physically active none had performed step aerobics previously.

EQUIPMENT

A Kistler forceplate (type 9287) was used to record the ground reaction forces. The outputs from the charge amplifiers were passed to a 14 bit analog to digital converter board in an IBM AT compatible computer. The computer collected the data at a rate of 200 Hz and calculated the Resultant Ground Reaction Forces (RGRF) which were stored on disk. Three standard benches were used with heights of 0.20, 0.25 and 0.30 m. The subjects wore the shoes that they would normally wear while exercising.

PROCEDURE

The force measurement system was calibrated immediately before and after the testing session and reset to zero prior to every data sample. An experienced step aerobic teacher lead the class, instructing the subjects in correct stepping technique. The most typical step pattern was used i.e. up left, up right, down left, down right with a cadence of 120 spm. The walking trial was completed at 130 spm and the jogging trial at 150 spm. Testing was structured along the lines of a typical step aerobic class with subjects rotating through the various trials. Five trials were completed by each subject, i.e. walking and jogging on the spot as performed in a traditional aerobic class, and stepping up and down off the 0.20, 0.25 and 0.30 m benches. Ten benches were placed around the room with one being in front of the forceplate. As the activities were performed, the subjects would rotate around the stations so that a different subject would be stepping on the forceplate. Once the subject's stepping pattern had been established, the computer collected 7.5 seconds of data and the subjects were instructed to move to the next station. The order of performing the trials was randomized across subjects to avoid any temporal effects due to fatigue or learning.

STATISTICAL ANALYSIS

The peak RGRF for each trial was normalized to body weight (BW) according to the methods of Scott and Winter (1990). This study examined the resultant of the GRF rather than the vertical forces in isolation as has been the methodology of other studies (1,3,5). The anterior-posterior GRF contributes to the internal forces on the legs (4) and so was included in the calculation of ground reaction force. The mean, standard deviation, maximum, minimum, range and coefficient of relative variation of peak RGRF was calculated for each of the five trials. A one-way repeated measures analysis of variance was used to determine the significance of differences between trials. A post hoc test using the Newman-Keuls method was applied to the data to determine in which trials the significant difference occurred.

RESULTS

Summary data for the peak RGRF across the five trials is provided in Table 1 with means and standard deviations for each trial presented in Figure 1. There were

significant differences in the peak RGRF achieved in the five trials ($F(4,45)=9.67, p<.01$). The post hoc tests indicated that the peak ground reaction forces during jogging were significantly higher than those of walking ($p<.01$) and stepping off the 0.20 m step ($p<.05$). The peak RGRF that occurred while stepping off the 0.30 m bench was significantly higher than walking ($p<.01$) and stepping off the 0.20 m step ($p<.05$). Stepping using the 0.25 m bench resulted in higher peak impact forces than walking ($p<.05$).

No significant differences were found between the peak impact forces that occur during jogging and stepping using either a 0.25 m or 0.30 m step.

TABLE 1. Summary statistics of peak ground reaction force for five trials

	Walk	Jog	Step 20	Step 25	Step 30
Mean (BW)	1.75	3.07	2.24	2.43	2.90
Std.Dev. (BW)	0.19	0.43	0.50	0.63	0.66
Variation (%)	10.71	14.00	22.18	25.77	22.85
Maximum (BW)	2.00	4.03	3.14	3.47	4.14
Minimum (BW)	1.37	2.54	1.54	1.55	2.07
Range (BW)	0.63	1.49	1.60	1.92	2.07

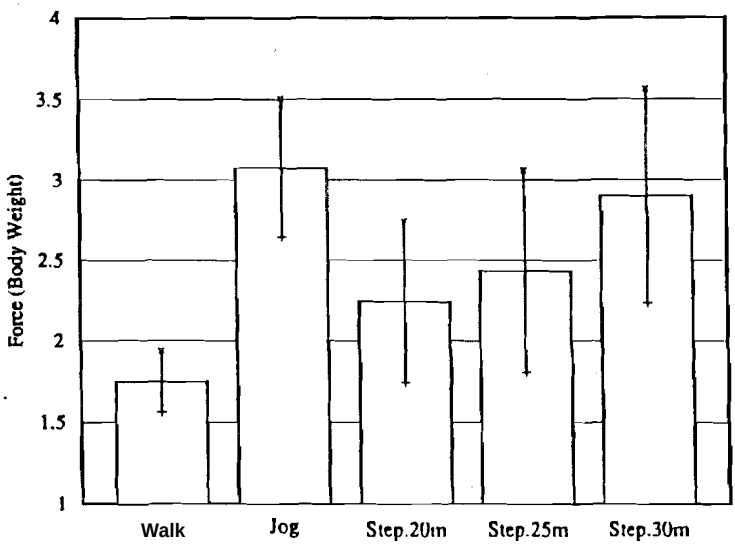

FIGURE 1. Mean peak ground reaction force for five trials

DISCUSSION

Contrary to the findings of Francis et al. (1990), no significant difference was found between the peak impacts experienced during running compared to stepping off a 0.25 m bench. Walking was found to produce significantly lower impacts than stepping off a 0.25 m bench ($p<.05$). Mean RGRF for all stepping trials measured were much higher than the 1.75 BW reported by Francis et al. (1990) using a 0.25 m bench. This difference may be accounted for in that this study measured resultant ground reaction force rather than just the vertical force component measured by Francis et al. (1990). The contribution of forces in the horizontal plane may be considerable and further investigation of this is required. Both the walk and jog trials in this study were performed on the spot as it is more common in the typical aerobic dance class than the translatory walking and running analyzed in the Francis et al. (1990) study. However, the peak GRF during running in both studies was approximately 3 BW and this compares with the results of other running studies (Frederick & Hagy, 1986; Mero, et. al., 1987; Scott & Winter, 1990). The mean peak GRF during walking was found to be 1.75 BW which was considerably higher than the 1.25 BW measured in the Francis et al. (1990) study. This is most likely related to the differences in methodology in that higher impacts could be expected during stationary walking. The differences between impacts during stationary and translatory walking require further investigation.

The difference in peak RGRF between the 0.20 m and 0.30 m bench heights ($p<.05$) indicates that increases in step height produce increases in RGRF. This aspect requires further investigation, especially in light of the practice of increasing bench heights as participants improve fitness and the element of competitiveness evident in some classes. The lowest bench tested, 0.20 m, did not produce impacts significantly higher than those for walking. This height or lower would appear to be safer for the beginning exerciser in terms of impacts through the lower limbs.

From Table 1 it should be noted that the coefficients of relative variation for peak RGRF were greater for each step condition than for the walking and jogging trials. This may indicate a larger variation in stepping forces possibly due to differences in technique.

A further avenue of investigation is the effect of various stepping cadences on the forces experienced. The Step Aerobic Manual recommends rates of no higher than 120 spm, however, many instructors are conducting classes at faster rates. Not only does the impact force need to be evaluated but also the safety of higher speed stepping technique.

CONCLUSIONS

It can be concluded that the RGRF experienced during step aerobics are significantly higher than those of walking especially at the higher bench heights of 0.25 and 0.30 meters, and that increases in bench height produce higher peak impact forces. Instructors and participants should be made aware of the importance of good shock

absorptive footwear and correct step technique emphasizing toe then heel foot plant and adequate knee flexion. The step heights used should be limited to the lower heights, preferably 0.20 m or less, if the impacts are to remain below values experienced during running.

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