STEP-EXERCISE MAY BE INCLUDED IN BONE HEALTH PROMOTION PROGRAMS

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Running title
STEP-EXERCISE AND BONE HEALTH

To the Editor of the Women in Sport and Physical Activity Journal:
The present paper entitled “STEP-EXERCISE MAY BE INCLUDED IN BONE HEALTH PROMOTION PROGRAMS”, by Rita Santos-Rocha, Maria Lourdes Machado and António Veloso, has not been published in another journal, is not under consideration elsewhere, and will not be submitted elsewhere before a final editorial decision from Women in Sport and Physical Activity Journal is rendered.
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STEP-EXERCISE MAY BE INCLUDED IN BONE HEALTH PROMOTION

1 PROGRAMS

4 Abstract
5 Physical exercise has been found to be effective in the prevention of osteoporosis, especially those activities that include impact loading. Activities such as walking, jogging and stair climbing, introduce stress to the skeleton through ground reaction forces (GRF). The analysis of GRF help to understand the magnitude and pattern of loading experienced by the body while in contact with the ground. Our purposes were to analyze the peak-GRF and loading-rate produced by Step-Exercise in 18 skilled females; and to investigate the effect of stepping-rate and step-pattern. Step-Exercise seems to produce greater loading than walking and at increased stepping rates its loading could be compared to those obtained during comfortable running. The results indicated that loading can be effectively controlled by varying stepping rate and step-patterns during classes, and how experienced subjects deal with the increase of external load. Controlled stepping exercise appears relatively safe with respect to the magnitude of loading.

Key words: exercise and health, peak ground reaction forces, repeated measures.

INTRODUCTION
23 Recreational Exercise aiming to improve or maintain health and fitness constitutes a group of physical activities performed by a large number of participants worldwide, regardless of age and physical or health status. The main objectives of these physical activities are to provide healthy mechanical and metabolic stimuli as well as fun. Besides its cardiovascular benefits, the organization of exercise sessions and exercise prescription, concerning rate and magnitude of skeletal loading, can improve the osteogenic potential of physical activity (Cullen et al., 2001; Turner & Robling, 2003).
31 Exercise Prescription concerns in a sequence of procedures aiming to adapt the stimuli of the different forms and modes of Exercise to participant's goals and needs, using the information of health and fitness assessment, respecting the main roles of Exercise and the safety of participants.
35 In what is concerned to health-related cardiovascular Exercise, plenty of well documented references can be found in literature. Those include the metabolic expenditure of several forms of physical activity (ACSM, 2005) and the step-by-step case studies developed in order to adapt the metabolic calculations to meet participants' goals of losing weight or improving cardiorespiratory fitness. To give a figurative example, considering that a person is running for 30 min at a comfortable speed, this kind of exercise could be considered a stimulus that can be translated in a “aerobic effort whose intensity is about 60% of the maximal oxygen uptake, which is consuming a certain amount of calories”, or in a “ mechanical effort of which vertical component of the ground reaction force is about 1600 Newton or about two times the person’s body weight and it has been applied around 1500 times on each feet”. In the first case, we are referring to the specific benefits of this exercise on the cardiorespiratory and immunitary systems and to the effects in body composition and cardiovascular health. In the second case, we are referring to the specific benefits of
this exercise on the musculoskeletal system and to the effects in body composition and bone health. Bone mineral density, osteoporosis and osteoporotic fractures have become one of the major health problems in Western countries (Cummings & Melton, 2002). Osteoporosis is a disease characterized by low bone mass and microarchitectural deterioration of bone tissue leading to enhanced bone fragility and a consequent increase in fracture risk (ACSM, 1995). As osteoporosis is more common in females, more exercise-related research has been directed at reducing the risk of osteoporotic fractures in women. Factors that influence fracture risk include skeletal fragility, frequency and severity of falls, and tissue mass surrounding the skeleton. Prevention of osteoporotic fractures, therefore, is focused on the preservation or enhancement of the material and structural properties of bone, the prevention of falls, and the overall improvement of lean tissue mass (ACSM, 1995). Normal physiological loading causes a range of deformation reactions (strains) in bone, including compression, tension, shear, torsion, and vibration. Bone exhibits an intrinsic ability to adapt to alterations in chronic loading to withstand future loads of the same nature (Wolff's Law). Adaptation of bone to load changes occurs via increased modeling and/or remodeling. Modeling is a process whereby bone tissue is either deposited or removed to modify the shape and size of a bone. Remodeling describes a process of bone resorption, followed (after a delay of roughly one month) by deposition of new bone (for approximately six months). While some level of remodeling is constantly occurring in normal bone, in bone undergoing adaptation to altered loading, the degree of remodeling increases substantially. The initial increase in resorption will render a bone relatively porous until the process of deposition can fully replace the lost tissue. During this prolonged replacement phase, bone is more susceptible to stress fracture by virtue of increased porosity (Beck, 2000). Physical exercise has been found to be effective in the prevention of osteoporosis, especially those activities that include impact loading (ACSM, 1995; Layne & Nelson, 1999; Wallace & Cumming, 2000; Witzke & Snow, 2000; Bauer et al., 2001; Nikander et al., 2005; Jämsä et al., 2006). Physical activity, particularly weight-bearing exercise, is thought to provide the mechanical stimuli or "loading" important for the maintenance and improvement of bone health, whereas physical inactivity has been implicated in bone loss and its associated health costs. Also, high-intensity resistance training, in contrast to traditional pharmacological and nutritional approaches for improving bone health in older adults, has the added benefit of influencing multiple risk factors for osteoporosis including improved strength and balance and increased muscle mass (Layne & Nelson, 1999). The cross-sectional study of Yung et al. (2005) indicated that regular participation in weight-bearing exercise in young people (18-22 years) might be beneficial for accruing peak bone mass and optimizing bone structure. The load-bearing capacity of bone reflects both its material properties, such as density and modulus, and the spatial distribution of bone tissue. These features of bone strength are all developed and maintained in part by forces applied to bone during daily activities and exercise. Functional loading through physical activity exerts a positive influence on bone mass in humans. The extent of this influence and the types of programs that induce the most effective osteogenic stimulus are still uncertain. While it is well-established that a marked decrease in physical activity, as in bed rest for example, results in a profound decline in bone mass, improvements in bone mass resulting from increased physical activity are less conclusive (ACSM, 1995). Kohrt et al. (1997) defined that activities such as walking, jogging and stair climbing, constitute a group of exercises that introduce stress to the skeleton through ground reaction forces (GRF); and activities such as weight lifting and rowing constitute a group of exercises that introduce stress to the skeleton through joint reaction forces (JRF). Both the GRF and the JRF exercise programs resulted in significant and similar increases in BMD of the whole body. Nikander et al. (2005) performed a research with 255 premenopausal female athletes and referred that the loadings that arise from high impacts or impacts from atypical...
loading directions seem to be effective. Also, the authors reported that high-impact loading (e.g. volleyball) and odd-impact loading (e.g. step aerobics and soccer) activities were associated with the highest body mineral density (BMD) of the femoral neck and bone strength (index Z) when compared to high-magnitude loading (e.g. weightlifting), low-impact loading (e.g. orienteering and cross-country skiing), and non-impact loading (e.g. swimming and cycling) activities. A recent publication studied for the first time the association between the intensity of physical activity and proximal femur BMD, using a long term quantification of daily activity based on the vertical component of the acceleration (Jämsä et al., 2006). It appears that strength and overall fitness can be improved at any age through a carefully planned exercise program. Unless the ability of the underlying physiologic systems essential for load bearing activity are restored, it may be difficult for many older women to maintain a level of activity essential for protecting the skeleton from further bone loss (ACSM, 1995).

Sports Biomechanics includes the study of recreational physical activity, none as Exercise Biomechanics. Two areas of research are of major interest: 1) the quantification or estimation of mechanical load acting on the biological structures; and 2) the study of biological effects of locally acting forces on living tissue; effects such as growth and development or overload and injuries (Brüggemann, 2005).

The major biological effects of forces include changes in the development of biological tissue and transportation of nutrients through the human body (Nigg, 2000). The effects of biomechanical loading applied on the Musculoskeletal System can be either biopositives or bionegatives. Load repetition generally does not result in injury during normal activity, although it has been suggested that repeated impacts such as the collision of the foot with the ground during locomotion can result in microtrauma (Hamill & Caldwell, 2001). Also, the magnitude of GRF has been associated, although never verified, with the high incidence of lower extremity injuries in fitness instructors (Rousanoglou & Boudolos, 2005).

Understanding the magnitude of loading is important for exercise prescription and to design rehabilitation programs. The vertical peak-GRF allows to characterize movement in terms of biomechanical loading. It has been suggested that there is an optimal amount of loading that healthy individuals should maintain and that loading above a certain limit might be related to the risk of injury (Shaw et al., 2001). High skeletal loading intensity has been defined as peak-GRF of greater than 4 times body-weight (BW), moderate intensity as 2-4 BW, and low intensity as GRF less than 2-BW, and a minimum osteogenic effect was related to 1-2 BW (Witzke & Snow, 2000; Shaw et al., 2001; Turner & Robling, 2003).

The human body has a number of mechanisms by which load is attenuated. On one hand, the body has structures such as fat pads on the plantar surface of the foot, cartilage in the joints and bone, and soft tissues surrounding the bone. On the other hand, there are also particular motions of the segments that attenuate shock. In the lower extremity, these include knee flexion, subtalar pronation, and ankle dorsiflexion (Hamill & Caldwell, 2001).

Step-Exercise was described in a previous study (Santos-Rocha et al., 2006). Most participants are female. Besides its cardiovascular benefits (Stanforth et al., 1993; Scharff-Olson et al., 1996; Kraemer et al., 2001; Kin Ilser et al., 2001) the structure of exercise sessions, concerning rate and magnitude of skeletal loading, may improve the osteogenic potential of physical activity (Cullen et al., 2001; Turner & Robling, 2003) because this activity involves a large number of loading cycles during each session (Santos-Rocha et al., 2006). When Step-ReebokTM program was presented its proponents claimed that ground reaction forces (GRF) were similar to those of walking (Reebok University Press, 1994). Two forms of controlling the intensity of the workout are by adjusting stepping-rate (125-150 beats-per-minute – bpm); and by selecting the types of movements included in choreography (e.g. propulsive movements). The characterization of Step Exercise has shown that classes are performed with a mean (±sd) stepping rate of 135±5 bpm and the mean
number of loading cycles performed was 4194.1±1055.2, ranging from 1874 to 7250, which might help to meet the recommendation of 10,000 steps a day (Wilde et al., 2001).

A major concern is how to control the intensity of the workout, maintaining safe and effective levels of mechanical load. The GRF of a Step session depend on the type and number of movements performed (Santos-Rocha et al., 2006). Regular exposure to moderately high magnitudes of force is desirable within certain levels, because mechanical stress will induce adaptation on biological structures, however the same forces might produce undesirable effects such as discomfort, pain and injury, especially when forces are too repetitive in a period of time (Miller, 1990; Nigg et al., 1995). Several authors referred that Step-Exercise seems to induce greater loading than walking, and at increased stepping-rates its impact loading could be compared to those obtained during comfortable running and high impact aerobics, but with lower risk of injury (Farrington & Dyson, 1995; Bezner et al., 1996; Hecko & Finch, 1996; Maybury & Waterfield, 1997; Williford et al., 1998; Santos-Rocha et al., 2002).

Most studies with Step-Exercise, reported the effects of vertical peak-GRF during the descending-phase of basic-step (Dyson & Farrington, 1995; Farrington & Dyson, 1995; Bezner et al., 1996; Hecko & Finch, 1996; Tagen & Zebas, 1996; Maybury & Waterfield, 1997; Scharrff-Olson et al., 1997; Wieczorek et al., 1997; Machado & Abrantes, 1998; Santos-Rocha et al., 2002; Santos-Rocha & Veloso, 2007). Few references reported the internal loading during Step-Exercise (Bezner et al., 1996; Santos-Rocha & Veloso, 2004). Also, one may be interested in the magnitude or in how fast the force is increasing or decreasing. The loading-rate describes this behavior. The quantification of the initial part of the vertical GRF curve may be effectively characterized by the loading-rate, due to the absence of an impact peak in certain cases. It is often assumed that the loading-rate is associated with the development of movement related injuries (Nigg, 2000).

We hypothesized that Step-Exercise is a low to moderate activity, and the step-patterns with propulsion should present higher load than non-propulsive movements, and loading increases with faster stepping-rate. Our purposes were to investigate the differences that exist between four stepping-rate conditions (125/130/135/140-bpm) and ascending and descending-phases of four step-patterns (basic-step/knee-lift/run-step/knee-hop) in the vertical-1st-peak (FZ) and in the vertical-1st-peak loading-rate (LR-FZ), during Step-Exercise.

METHODS
Eighteen Step-experienced females (mean±sd age 29.1±6.8 years; body mass 58.9±6.4kg; height 1.66±0.06m; Caucasian) with no history of lower limb trauma or disease, volunteered to participate in the study. These women were experienced fitness instructors who were certified and/or graduate in sport sciences and possessed at least 3 years of teaching experience. They were led through a sequence of 8 stepping tasks: right-basic-step, right-knee-lift, left-basic-step, left205 knee-lift, right-run-step, right-knee-hop, left-run-step, left-knee-hop. This procedure was adopted in order to ensure mechanical balance between both lower limbs. No arm movements were added. Verbal instruction was provided during the tests. Fitness music was used to maintain cadence. All experimental trials were conducted in a “crescent cadence” order. These procedures were adopted so the result would reflect typical class conditions. Body-weight was measured using the Kistler force platform. The study was approved by the review committee of the Faculty. The subjects were allowed to familiarize to each speed before data collection, and was given approximately 60-90s of rest between trials so as to reduce the potential effects of fatigue. In order to reduce error participants wore similar shoes, because the type of footwear influence braking and propulsive forces, and alter foot mechanics (Hennig & Milani, 1995; Mitchell et al., 1996).
Our previous study showed that metal force-platforms surfaces are suitable to assess mechanical load of stepping, with experienced subjects (Santos-Rocha & Veloso, 2007). The movements were performed on the AMTI (Advanced Mechanical Technology, Inc., Watertown, MA) force-platform (17cm height) for stepping-up (substituting the step-bench) and on the KISTLER (Kistler AG, Winterthur, Switzerland) force-platform on ground level for stepping-down. Acqknowledge-3.7.3. (BIOPAC Systems, Inc., Goleta, CA) was used to collect GRF at 1000-Hz and process data. Data were smoothed with a Hamming low pass digital filter of 8-Hz. Peak values were collected and normalized to BW in Excel (Microsoft Corporation, USA). Loading-rate (N/s) was calculated \(\text{loading-rate} = \frac{\text{peak-force-N}}{\text{time-to-peak-s}}\) and normalized to BW/s. Figure 1 represents the identification of the movements studied, and shows the phases of reception during which the peak values were collected.

Using SPSS (Statistical Package for the Social Sciences, Chicago, IL) the vertical-1st peak \((FZ)\) in BW and the vertical-1st peak loading-rate \((LR-FZ)\) in BW/s were analyzed statistically. Descriptive statistics are reported and a one-way ANOVA for repeated measures \((RM)\) was used to determine whether there where significant differences between the conditions of stepping-rate and step-patterns, resulting in two within-subjects factors. Prior to perform RM, Kolmogorov-Smirnov normality test and Mauchly’s test of sphericity were conducted. In the cases sphericity was not assumed the Huynh-Feldt correction was used. The pairwise comparisons with the Bonferroni confidence interval adjustments were used to identify where differences could be found. The level of statistical significance was set at \(p \leq 0.050\) (Vincent, 2005).

RESULTS

The results showed that during stepping at different cadences the vertical GRF curves were very regular and repetitive among subjects, despite different interval time among conditions. We observed the absence of impact peaks in the movements analyzed. Table 1 shows the descriptive statistics of FZ and LR-FZ. Table 2 shows the results of ANOVA-RM and Bonferroni pairwise comparisons of the parameters analyzed, as well as the summary of the confirmation of the hypothesis. The test of within-subjects effects has shown no interaction between step-pattern and stepping-rate in LR-FZ (descending-phase). There was interaction between conditions in relation to: FZ (ascending-phase, \(p=0.001\); descending-phase, \(p=0.011\)) and LR-FZ (ascending-phase, \(p=0.002\)).

DISCUSSION

The GRF may provide a surrogate measure for the strain experienced by bone on a variety of loading activities such as Step movements. The analysis of GRF has shown that higher loads occur during the reception on the step-bench (in propulsion movements: run-step and knee-hop) and during the reception on the ground (in non-propulsion movements: basic-step and knee-lift). The results of FZ in basic-step (descending-phase) were greater than those reported by other authors that used slower cadences (120-bpm) (Farrington & Dyson, 1995; Bezner et al., 1996; Maybury & Waterfield, 1997) but are in line with those obtained by Teriet and Finch (1997) and with those obtained in our previous studies (Santos-Rocha et al., 2002). In knee-lift (descending-phase) the results were greater than those reported by Farrington and Dyson (1995) that used slower cadences (120-bpm). The results in both phases are in line with those obtained by Panda (2003). In run-step the mean FZ was 2.3-BW (ascending-phase) and 1.8-BW (descending-phase). Tagen and Zebas (1996) reported 2.5-BW during ascending-phase of run (126-bpm). The results of FZ in knee-hop (ascending-phase) are in line with those reported by Machado and Abrantes (1998) that also used slower cadences (120-bpm). The results for both phases of all movements performed at 130 and 140-bpm were around 0.1-0.2
smaller than those obtained in our previous studies using pressure insoles (Santos-Rocha & Veloso, 2007). In walking FZ had a maximum value of 1-1.2 BW, and in running, can achieve 3-5 BW (Miller, 1990). Therefore, Step-Exercise seems to produce greater loading than walking and at increased stepping-rates its loading could be compared to those obtained during comfortable running.

The results obtained for vertical peak-forces suggest that Step-Exercise is a low to moderate activity, depending on the inclusion of non-propulsion or propulsion, and stepping-rate (with experienced participants). Our results support the conclusion of Scharff-Olson et al. (1997) that experience with Step-Exercise may afford an ability to make uniform and force-absorbing adjustments in FZ at increased speeds. Teriet and Finch (1997) suggested that the faster loading and unloading-rates of the musculature due to the faster stepping-rates (122 to 130-bpm) caused less control of the movement, resulting in a 4% increase in the FZ and therefore, the use of faster tempos in a beginning level class could be a source of elevated risk for potential injury.

The time of peak FZ, ranged 0.20-0.28s (ascending-phase) and 0.21-0.22s (descending-phase). The interval time decreased with stepping-rate, meaning that the same movement has to be performed in the same form but with less time. This is reflected by the increase in loading-rate. Loading-rate was associated to 77 BW/s in running speed at 3m/s (Miller, 1990). In the present study, the mean LR-FZ increased with stepping-rate, and the greatest value was found in ascending-phase of run-step. In descending-phase it increased significantly with stepping-rate. The larger peaks and loading-rates indicate a loss of shock absorbing capacity. This might increase their susceptibility to lower extremity overuse injuries.

The results indicate that lower extremity external loading can be effectively controlled by varying stepping-rate during Step classes, and by choosing movements mechanically similar to those analyzed in the present study. As an example, the run299 step clearly induced greater forces and loading-rate, which might be more related to injury.

These findings indicate the relative contributions of stepping-rate and different choreographic movements to the external forces experienced during Step-Exercise. Further research is needed focusing other step-patterns in order to select those that are more appropriate to be included in Exercise and Rehabilitation programs. The present investigation provides biomechanical data that may be used as a basis of comparison with patients, elderly people and beginners that participate in Step programs. However, the present results are based on a sample of 18 experienced and physically active instructors, thus, both kinematics and force characteristics of the tasks may be different if participants with less experience in Step are used, and establishing norms for other populations requires understanding other factors that affect GRF. Also, these results are related to the mechanical characteristics of this physical activity and might be analyzed under the ergonomic perspective, since the group of subjects was constituted by experienced Step instructors. The results suggest that experienced steppers are capable of stepping at different cadences, with generally similar patterns of kinematics and kinetics.

Our results showed that increasing step frequency leads to an increase in the mechanical load, which appears to be supported by adaptations of the movement technique which might be related with the increasing GRF. However, if technique adaptations occur, especially in the knee joint, together with greater GRF and moments of force and decreased time for contact and force transfer, the stepping rate, being one of the most important determinants of exercise intensity, particularly above 135-bpm, should be chosen carefully in classes, having always in consideration the participants’ experience in this activity.

The results contribute to understand how skilled participants deal with the increase of the external load during Step-Exercise. Skilled participants appear to control the increase of stepping-rate by means of knee and ankle adaptations. These joints might be in greater risk of injury in the case of overuse, especially the knee.
joint. In order to prevent injury, proper instruction should be provided in relation to foot placement on the step-bench and on the ground, as well as information concerning knee flexion. Our results indicate that lower extremity external loading can be effectively controlled by varying stepping-rate during Step classes and selecting step-patterns. The results are also relevant to determine which movements and cadences can be recommended to be included in rehabilitation programs where walking and running are prescribed. Assuming that walking or running are "safe" activities to be included in Exercise and rehabilitation programs, oriented stepping exercise appear relatively safe with respect to the magnitude of loading.

In conclusion, Step-Exercise is performed using music that sets movement cadence which involves the repetition of exercises that induce peak-GRF of low magnitude moderate activity (1-2.5 BW), depending on step-patterns included, but of high frequency (3750-4050 loading cycles during a 30-min session, depending on the stepping-rate, using music speed at 125/135-bpm) (Santos-Rocha et al., 2006). We suggest that this recreational activity may be included in bone health promotion programs.

References


47. 27

48. 26

49. 0.00

144.97
N AMTI_Fx 0.00 436.00 872.01 1308.01 N AMTI_Fz 0.00 495.81 991.61 1487.42 N FZ -315.19 -157.59 0.00 157.59 N FX Right Basic Step Right Run Step Left Basic Step Left Run Step Right Knee Lift Left Knee Lift Right Knee Hop Left Knee Hop GRF

Figure 1. Anterior-posterior (AMTI_Fx and FX) and vertical (AMTI_Fz and FZ) components of the ground reaction force of one representative subject at 140 beats per minute. The arrows identify the phases during which the peak values were collected within the sequence of the 8 Step movements using the vertical component of the ground reaction force, during the ascending (AMTI Fz) and descending (FZ) phases of the movements: black arrows show basic-step; grey arrows show knee-lift; black dashed arrows show run-step; and grey dashed arrows show knee-hop.

Table 1. Descriptive statistics of the peak vertical ground reaction force (FZ) normalized to body weight (BW) and of the loading rate of the peak vertical ground
501 reaction force normalized to body weight per second (BW/s), during ascending phase and descending phase of four Step-patterns (basic-step, knee-lift, run-step and knee-hop) performed at four stepping-rates (125, 130, 135 and 140 bpm).

**BASIC-STEP KNEE-LIFT RUN-STEP KNEE-HOP**

**BPM 125 130 135 140 125 130 135 140 125 130 135 140 125 130 135 140 125 130 135 140**

**ASCENDING PHASE – PEAK FZ GRF (BW)**

<table>
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<tr>
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**DESCENDING PHASE – PEAK FZ GRF (BW)**

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**ASCENDING PHASE – LOADING RATE PEAK FZ (BW/s)**

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<td>1.2</td>
<td>4.1</td>
<td>8.9</td>
<td>4.7</td>
</tr>
<tr>
<td>BPM 140</td>
<td>6.3</td>
<td>1.3</td>
<td>4.1</td>
<td>9.3</td>
<td>5.2</td>
</tr>
</tbody>
</table>

**DESCENDING PHASE – LOADING RATE PEAK FZ (BW/s)**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPM 125</td>
<td>8.1</td>
<td>1.4</td>
<td>4.9</td>
<td>10.9</td>
<td>6.0</td>
</tr>
<tr>
<td>BPM 130</td>
<td>8.2</td>
<td>1.3</td>
<td>4.7</td>
<td>11.1</td>
<td>6.4</td>
</tr>
<tr>
<td>BPM 135</td>
<td>8.5</td>
<td>1.8</td>
<td>5.8</td>
<td>12.8</td>
<td>7.0</td>
</tr>
<tr>
<td>BPM 140</td>
<td>8.5</td>
<td>1.6</td>
<td>5.4</td>
<td>12.5</td>
<td>7.1</td>
</tr>
</tbody>
</table>

Table 2. Summary of the results of the statistical analysis (ANOVA repeated measures) performed with vertical peak ground reaction forces (FZ) parameters.

508 Significantly statistical differences (\(p \leq 0.05\)) were found among the following conditions of stepping-rate and step-pattern:

**STEPPING-RATE STEP-PATTERN**

Peak FZ ascending

ANOVA-RM \(F(3,105)=12.652\) (\(p=0.000\))

All (\(p \leq 0.013\)); except 125-130 bpm; except 135-140 bpm

Increases as stepping-rate increases

Hypothesis confirmed

\(F(2,086,73.005)=441.251\) (\(p=0.000\))

All (\(p=0.000\))

Greater values in run-step

Hypothesis confirmed

Peak FZ descending

\(F(3,105)=5.901\) (\(p=0.001\))

125-135 bpm (\(p=0.001\)); 125-140 bpm (\(p=0.015\))

Increases as stepping-rate increases

Hypothesis confirmed

\(F(2,200,77.000)=14.301\) (\(p=0.000\))
basic-hop \( (p=0.000) \); knee lift-hop \( (p=0.003) \); run-hop \( (p=0.000) \)
Hypothesis not confirmed

**Loading rate FZ**

**ascending**

phase

\[ F(3,105)=17.838 \, (p=0.000) \]
125-140 bpm \( (p=0.000) \); 130-140 bpm \( (p=0.000) \);
135-140 bpm \( (p=0.000) \)
Increases as stepping-rate increases
Hypothesis confirmed

\[ F(2.398,83.925)=147.162 \, (p=0.000) \]
All \( (p=0.000) \)
Greater values in **run-step**
Hypothesis confirmed

**Loading rate FZ**

**descending**

phase

\[ F(2.715,95.041)=8.432 \, (p=0.000) \]
125-135 bpm \( (p=0.000) \); 125-140 bpm \( (p=0.000) \)
Increases as stepping-rate increases
Hypothesis confirmed

\[ F(3,105)=8.770 \, (p=0.000) \]
basic-hop \( (p=0.000) \); run-hop \( (p=0.003) \)
Hypothesis not confirmed

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There are no competing interests.
31 October 2008

Dear Drs. Santos and Rocho,

Thank you for submitting your manuscript to WSPAJ. As you know, it has been accepted for publication. Because of an onslaught of submissions and acceptance notifications, your article will be published in the Spring, 2009 edition.

We sincerely appreciate your contribution to the Women in Sport and Physical Activity Journal. We look forward to further submissions from you and your colleagues.

All the best!

Prof Dr Darlene A Kluka
Editor: WSPAJ

Prof Dr Anneliese Goslin
Associate Editor: WSPAJ