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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Date of submission: October 8, 2007

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Abstract
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
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 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).

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.

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
105 loading directions seem to be effective. Also, the authors reported that high-impact
106 loading (e.g. volleyball) and odd-impact loading (e.g. step aerobics and soccer)
107 activities were associated with the highest body mineral density (BMD) of the femoral
108 neck and bone strength (index Z) when compared to high-magnitude loading (e.g.
109 weightlifting), low-impact loading (e.g. orienteering and cross-country skiing), and
110 non-impact loading (e.g. swimming and cycling) activities. A recent publication
111 studied for the first time the association between the intensity of physical activity and
112 proximal femur BMD, using a long term quantification of daily activity based on the
113 vertical component of the acceleration (Jämsä et al., 2006). It appears that strength
114 and overall fitness can be improved at any age through a carefully planned exercise
115 program. Unless the ability of the underlying physiologic systems essential for load
116 bearing activity are restored, it may be difficult for many older women to maintain a
117 level of activity essential for protecting the skeleton from further bone loss (ACSM,
118 1995).
119 Sports Biomechanics includes the study of recreational physical activity, none
120 as Exercise Biomechanics. Two areas of research are of major interest: 1) the
121 quantification or estimation of mechanical load acting on the biological structures;
122 and 2) the study of biological effects of locally acting forces on living tissue; effects
123 such as growth and development or overload and injuries (Brüggemann, 2005).
124 The major biological effects of forces include changes in the development of
125 biological tissue and transportation of nutrients through the human body (Nigg,
126 2000). The effects of biomechanical loading applied on the Musculoskeletal System
127 can be either biopositives or bionegatives. Load repetition generally does not
128 result in injury during normal activity, although it has been suggested that repeated
129 impacts such as the collision of the foot with the ground during locomotion can result
130 in microtrauma (Hamill & Caldwell, 2001). Also, the magnitude of GRF has been
131 associated, although never verified, with the high incidence of lower extremities
132 injuries in fitness instructors (Rousanoglou & Boudolos, 2005).
133 Understanding the magnitude of loading is important for exercise prescription
134 and to design rehabilitation programs. The vertical peak-GRF allows to characterize
135 movement in terms of biomechanical loading. It has been suggested that there is an
136 optimal amount of loading that healthy individuals should maintain and that loading
137 above a certain limit might be related to the risk of injury (Shaw et al., 2001). High
138 skeletal loading intensity has been defined as peak-GRF of greater than 4 times
139 body-weight (BW), moderate intensity as 2-4 BW, and low intensity as GRF less than
140 2-BW, and a minimum osteogenic effect was related to 1-2 BW (Witzke & Snow,
141 2000; Shaw et al., 2001; Turner & Robling, 2003).
142 The human body has a number of mechanisms by which load is attenuated.
143 On one hand, the body has structures such as fat pads on the plantar surface of the
144 foot, cartilage in the joints and bone, and soft tissues surrounding the bone. On the
145 other hand, there are also particular motions of the segments that attenuate shock. In
146 the lower extremity, these include knee flexion, subtalar pronation, and ankle
dorsiflexion (Hamill & Caldwell, 2001).
148 Step-Exercise was described in a previous study (Santos-Rocha et al., 2006).
149 Most participants are female. Besides its cardiovascular benefits (Stanforth et al.,
150 1993; Scharff-Olson et al., 1996; Kraemer et al., 2001; Kin Ilser et al., 2001) the
151 structure of exercise sessions, concerning rate and magnitude of skeletal loading,
152 may improve the osteogenic potential of physical activity (Cullen et al., 2001; Turner
153 & Robling, 2003) because this activity involves a large number of loading cycles
154 during each session (Santos-Rocha et al., 2006). When Step-ReebokTM program was
155 presented its proponents claimed that ground reaction forces (GRF) were similar to
156 those of walking (Reebok University Press, 1994). Two forms of controlling the
157 intensity of the workout are by adjusting stepping-rate (125-150 beats-per-minute –
158 bpm); and by selecting the types of movements included in choreography (e.g.
159 propulsive movements). The characterization of Step Exercise has shown that
160 classes are performed with a mean (±sd) stepping rate of 135±5 bpm and the mean
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; Scharff-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-platform 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 (loading-rate=peak-force-N/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 were 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 and 1.8-BW in ascending-phase and 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
272 smaller than those obtained in our previous studies using pressure insoles (Santos-
273 Rocha & Veloso, 2007). In walking FZ had a maximum value of 1-1.2 BW, and in
274 running, can achieve 3-5 BW (Miller, 1990). Therefore, Step-Exercise seems to
275 produce greater loading than walking and at increased stepping-rates its loading
276 could be compared to those obtained during comfortable running.
277 The results obtained for vertical peak-forces suggest that Step-Exercise is a
278 low to moderate activity, depending on the inclusion of non-propulsion or propulsion,
279 and stepping-rate (with experienced participants). Our results support the conclusion
280 of Scharff-Olson et al. (1997) that experience with Step-Exercise may afford an ability
281 to make uniform and force-absorbing adjustments in FZ at increased speeds. Terjet
282 and Finch (1997) suggested that the faster loading and unloading-rates of the
283 musculature due to the faster stepping-rates (122 to 130-bpm) caused less control of
284 the movement, resulting in a 4% increase in the FZ and therefore, the use of faster
285 tempos in a beginning level class could be a source of elevated risk for potential
286 injury.
287 The time of peak $F_Z$, ranged 0.20-0.28s (ascending-phase) and 0.21-0.22s
288 (descending-phase). The interval time decreased with stepping-rate, meaning that
289 the same movement has to be performed in the same form but with less time. This is
290 reflected by the increase in loading-rate. Loading-rate was associated to 77 BW/s in
291 running speed at 3m/s (Miller, 1990). In the present study, the mean $LR-F_Z$
292 increased with stepping-rate, and the greatest value was found in ascending-phase
293 of run-step. In descending-phase it increased significantly with stepping-rate. The
294 larger peaks and loading-rates indicate a loss of shock absorbing capacity. This
295 might increase their susceptibility to lower extremity overuse injuries.
296 The results indicate that lower extremity external loading can be effectively
297 controlled by varying stepping-rate during Step classes, and by choosing movements
298 mechanically similar to those analyzed in the present study. As an example, the run299
300 step clearly induced greater forces and loading-rate, which might be more related to
301 injury.
302 The findings indicate the relative contributions of stepping-rate and different
303 choreographic movements to the external forces experienced during Step-Exercise.
304 Further research is needed focusing other step-patterns in order to select those that
305 are more appropriate to be included in Exercise and Rehabilitation programs. The
306 present investigation provides biomechanical data that may be used as a basis of
307 comparison with patients, elderly people and beginners that participate in Step
308 programs. However, the present results are based on a sample of 18 experienced
309 and physically active instructors, thus, both kinematics and force characteristics of
310 the tasks may be different if participants with less experience in Step are used, and
311 establishing norms for other populations requires understanding other factors that
312 affect GRF. Also, these results are related to the mechanical characteristics of this
313 physical activity and might be analyzed under the ergonomic perspective, since the
314 group of subjects was constituted by experienced Step instructors. The results
315 suggest that experienced steppers are capable of stepping at different cadences,
316 with generally similar patterns of kinematics and kinetics.
317 Our results showed that increasing step frequency leads to an increase in the
318 mechanical load, which appears to be supported by adaptations of the movement
319 technique which might be related with the increasing GRF. However, if technique
320 adaptations occur, especially in the knee joint, together with greater GRF and
321 moments of force and decreased time for contact and force transfer, the stepping321
322 rate, being one of the most important determinants of exercise intensity, particularly
323 above 135-bpm, should be chosen carefully in classes, having always in
324 consideration the participants’ experience in this activity.
325 The results contribute to understand how skilled participants deal with the
326 increase of the external load during Step-Exercise. Skilled participants appear to
327 control the increase of stepping-rate by means of knee and ankle adaptations. These
328 joints might be in greater risk of injury in the case of overuse, especially the knee
328 joint. In order to prevent injury, proper instruction should be provided in relation to
329 foot placement on the step-bench and on the ground, as well as information
330 concerning knee flexion. Our results indicate that lower extremity external loading
331 can be effectively controlled by varying stepping-rate during Step classes and
332 selecting step-patterns. The results are also relevant to determine which movements
333 and cadences can be recommended to be included in rehabilitation programs where
334 walking and running are prescribed. Assuming that walking or running are "safe"
335 activities to be included in Exercise and rehabilitation programs, oriented stepping
336 exercise appear relatively safe with respect to the magnitude of loading.
337 In conclusion, Step-Exercise is performed using music that sets movement
338 cadence which involves the repetition of exercises that induce peak-GRF of low
339 magnitude moderate activity (1-2.5 BW), depending on step-patterns included, but of
340 high frequency (3750-4050 loading cycles during a 30-min session, depending on the
341 stepping-rate, using music speed at 125/135-bpm) (Santos-Rocha et al., 2006). We
342 suggest that this recreational activity may be included in bone health promotion
343 programs.
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344
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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
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**

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Peak FZ (BW)</th>
<th>Loading Rate Peak FZ (BW/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASCENDING PHASE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPM 125</td>
<td>1.2 1.0 1.0 1.0</td>
<td>5.3 5.0 4.7 4.4</td>
</tr>
<tr>
<td>130</td>
<td>1.2 1.1 1.1 1.1</td>
<td>5.2 4.9 4.6 4.3</td>
</tr>
<tr>
<td>135</td>
<td>1.2 1.1 1.1 1.1</td>
<td>5.1 4.8 4.5 4.2</td>
</tr>
<tr>
<td>140</td>
<td>1.2 1.1 1.1 1.1</td>
<td>5.0 4.7 4.4 4.1</td>
</tr>
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<table>
<thead>
<tr>
<th>Conditions</th>
<th>Peak FZ (BW)</th>
<th>Loading Rate Peak FZ (BW/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DESCENDING PHASE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BPM 125</td>
<td>1.7 1.6 1.6 1.6</td>
<td>8.2 7.9 7.6 7.3</td>
</tr>
<tr>
<td>130</td>
<td>1.7 1.6 1.6 1.6</td>
<td>8.1 7.8 7.5 7.2</td>
</tr>
<tr>
<td>135</td>
<td>1.7 1.6 1.6 1.6</td>
<td>8.0 7.7 7.4 7.1</td>
</tr>
<tr>
<td>140</td>
<td>1.7 1.6 1.6 1.6</td>
<td>7.9 7.6 7.3 7.0</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. Significantly statistical differences (p≤0.050) were found among the following 509 conditions of stepping-rate and step-pattern:

**STEPPING-RATE STEP-PATTERN**

**Peak FZ ascending phase**

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

All (p≤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 phase**

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

Acknowledgements: POCI 2110 - POCI/DES/61761/2004
The authors wish to thank all participants of this study; to Helô Isa André, MSc and Maria João Valamatos, MSc (Faculty of Human Kinetics) and to Maria Fátima Ramalho, MSc (Sport Sciences School of Rio Maior) for their help in data collection; to Pedro Aguiar, MSc (National School of Public Health) and to Isabel Carita, PhD (Faculty of Human Kinetics) for their advice in statistical procedures.

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
Further, there is some evidence that exercise-induced gains in bone mass in children are maintained into adulthood, suggesting that physical activity habits during childhood may have long-lasting benefits on bone health. Thus, pharmacologic therapy for the prevention of osteoporosis may be indicated even for those postmenopausal women who are habitually physically active. Why is bone health important? Your bones are continuously changing—a new bone is made and old bone is broken down. When you’re young, your body makes new bone faster than it breaks down old bone, and your bone mass increases. Most people reach their peak bone mass around age 30. He or she might recommend a bone density test. The results will help your doctor gauge your bone density and determine your rate of bone loss. By evaluating this information and your risk factors, your doctor can assess whether you might be a candidate for medication to help slow bone loss. Exercise and bone health. American Academy of Orthopaedic Surgeons. https://orthoinfo.aaos.org/en/staying-healthy/exercise-and-bone-health/. Accessed Jan. exercise programmes for health promotion and rehabilitation. Thus, the aim of this article is to... may have proved effective in other contexts, for example, in the promotion of health. Further, at the infancy of resistance training studies. Furthermore, resistance training, and not aerobic training, may increase bone mineral density by as much as 1−3% (Westcott et al, 2009). Resistance training has also been shown.
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