Introduction

Skills are often performed under fatigue conditions. According to the hypothesis of specificity of training practice conditions should reflect the conditions at which the learned skill are to be applied in order for transfer to be optimal. Thus, learning in a state of fatigue should facilitate performance when fatigue is encountered and learning in a state of non-fatigued should be advantageous for non-fatigue performance (Arnett et al., 2000). Previous studies show mixed results (Caron, 1972; Godwin & Schmidt, 1971, Williams et al., 1976; Williams et al., 1979) with some indications that moderate levels of fatigue positively affect learning (Anshel & Novak, 1989). None of the reviewed studies addressed the issue of learning a timing task of sub-maximal explosive effort. The purpose of this study was to investigate the specificity of training in learning a sub-maximal vertical jump under conditions of anaerobic fatigue.

Methods

Subjects: 20 males aged 20-30 were randomly divided into fatigue (FG) and non-fatigue groups (NFG).

Task: The learning task was to perform a vertical jump to a height of 20 cm above standing height, at exactly 1.5 second from presentation of a visual signal. Initial position was erect standing. Hands were placed on the hips throughout the jump. General feedback was provided after each trial during the learning session but not during pre and post-tests. Feedback included verbal indicators as follows: "Very good" when the time was between 1.4 and 1.6 seconds, "Lengthen your performance" when the result was shorter than 1.4 seconds and "Shorten your performance" when the time exceeded 1.6 seconds.

Instrumentation: A pair of photocells, interfaced with a computer, were pre-positioned at the target height. Task time was measured from the presentation of a visual signal on the computer screen, to the crossing of the beam line by the top of the S’s head. Ground reaction forces (GRF) were recorded by means of a Kistler force plate interfaced with a computer by means of a Keithley A to D converter. Performance in the sagittal plane was filmed with a Panasonic VHS 450 camera at 60 fps and later digitized using APAS. The best trial from the pre-test and the best trial from the post were selected for digitization. A visual signal in the filming field was used to synchronize the filmed data with the photocells and force plate data.

Model: A four-segment model, which included the foot, shank, thigh and trunk + head + upper extremities, was adopted for kinematic analysis of the ankle, knee and hip.

Fatigue task: Wingate Anaerobic Test (WAT) was used to induce fatigue. The WAT was performed on Stairmaster Spinnaker 3000 electronic bicycle ergometer.

Design: The first session included 6 pre-test sub-maximal vertical jumps, three before WAT and three after WAT. The third session included a similar post-test. The second session included two sets of ten learning trials with 30 seconds intervals between trials and a 1 min interval between sets. Ss in the FG performed a full 30 seconds WAT prior to the learning trials and a shorter 20 seconds WAT between sets. Ss in the NFG rested during those two time intervals.

Statistical Analysis: Variables were analyzed by means of a three way ANOVA (learning condition/group * pre-post * test condition) with $\alpha < .05$.

Results and Discussion

Absolute Error time (AET), reaction time (RT) and movement time (MT) were computed from the photocells and force platform data. Results are presented in table 1.
Being the performance criterion, AET provided the main evidence for evaluation of the hypothesis of specificity of training. Both groups undershot target time during pre-test. A significant interaction between treatments (groups) and pre/post tests in AET time indicates a greater improvement in the NFG than in the FG. There was no effect of fatigue versus non-fatigue testing conditions on performance in any of the temporal variables or the kinematic variables. These results do not support the hypothesis of specificity of fatigue during learning because the NFG improved more than the FG when tested in both fatigue and non-fatigue conditions. Thus, learning under non-fatigue conditions seems to be favorable for learning as a preparation for performance in either fatigue or non-fatigue testing conditions. The results do not support those of Arnet et al. (2000) with regard to the advantage of learning under conditions of anaerobic fatigue while performing a stability task under fatigued conditions among males. However, the results are in agreement with the lack of such advantage found by Arnet et al. (2000) in females, and by Williams et al. (1979) with regard to learning under aerobic fatigue conditions. They also concur with those of Godwin and Schmidt (1971) with regard to learning a discrete motor skill under a state of muscular fatigue.

### Table 1: means, standard deviations and significant effect of Error Time, Reaction Time and Movement Time.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>TEST</th>
<th>FG Fatigue</th>
<th>Non-fatigue</th>
<th>NFG Fatigue</th>
<th>Non-fatigue</th>
<th>Significant Statistical Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Time (sec*10^-2)</td>
<td>Pre</td>
<td>35.6 (14.4)</td>
<td>34.5 (13.9)</td>
<td>43.0 (24.1)</td>
<td>44.1 (18.9)</td>
<td>G*P P</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>15.0 (12.7)</td>
<td>15.5 (12.6)</td>
<td>7.3 (7.5)</td>
<td>7.4 (4.9)</td>
<td></td>
</tr>
<tr>
<td>Reaction Time (sec*10^-2)</td>
<td>Pre</td>
<td>38.7 (26.2)</td>
<td>32.7 (20.5)</td>
<td>30.2 (21.6)</td>
<td>27.7 (17.6)</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>44.7 (22.8)</td>
<td>48.5 (24.2)</td>
<td>49.4 (22.8)</td>
<td>48.1 (18.5)</td>
<td></td>
</tr>
<tr>
<td>Movement Time (sec*10^-2)</td>
<td>Pre</td>
<td>60.9 (19.1)</td>
<td>68.9 (20.2)</td>
<td>72.7 (22.1)</td>
<td>77.2 (26.5)</td>
<td>P</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>86.8 (23.0)</td>
<td>85.3 (23.0)</td>
<td>88.4 (17.1)</td>
<td>88.1 (21.2)</td>
<td></td>
</tr>
</tbody>
</table>

Statistical effects: P= pre/post effect; G= group effect, F= test condition effect.

RT, MT time and selected kinematic variables were tested in order to assess whether the two groups differ in movement organization. In both groups there was an increase in mean RT (+0.15 sec) and mean MT (+0.18 sec) but not in flight time. The indication is that preliminary undershooting is compensated for in the process of learning mainly by elongation of the temporal components which proceed flight. There was no significant change in the duration of the push off phase in the NFG but it increased significantly in the FG (Fig. 1). Hence, adaptive changes in MT of the NFG are taking place only during the preparatory downward motion while those of the FG involve lengthening of both downward and push off phases. Learning under fatigue also elicited different kinematic adjustments than learning under non-fatigue conditions, which reflect different control mechanisms. Learning under non fatigued conditions was accompanied by increase in the mean angular velocities at takeoff at the hip (Fig 2) and the knee (Fig3), and a decreased in mean knee angle at takeoff (Fig4). The increased angular velocities were accompanied by increase in the range of motion and a greater knee and hip flexion at the onset of the push off phase. In the FG mean angular velocity at the hip and knee decreased. It seems that while the NFG adopted a strategy of greater range of motion and greater velocity at takeoff, the FG attempted to control the timing by maintaining the same range of motion combined with slower movements. This strategy may reflect the state of muscular fatigue. No significant effects were noted in the impulse of the GRF.
References


