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POSTURAL SWAY RESPONSE TO REBOUND JUMPS OF DIFFERENT DURATION

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ABSTRACT
Purpose. The study compares the sway variables after continuous CMJs eliciting different level of proprioceptive stimulation determined by percentage of max height of the jump. **Basic procedures.** A group of 11 aerobic dancers performed in random order repeated jumps with maximal effort until the jump height dropped to 75%, 50%, and 25% of previously established max jump achieved in non-fatigued conditions. The height of CMJs was calculated from flight times registered by FiTRO Jumper. Thirty seconds prior to and two minutes after exercises the COP velocity was registered at 100 Hz by means of posturography system FiTRO Sway Check based on dynamometric platform. **Main findings.** Results showed that max height of the jump (MJ) decreased from 27.7 ± 2.8 cm to 20.1 ± 2.6 cm when subjects matched 75% of 1MJ, to 13.8 ± 1.6 cm at 50% of 1MJ, and to 6.9 ± 0.8 cm at 25% of 1MJ. The COP velocity was significantly ($p \leq 0.01$) higher after jumps dropped to 75% of 1MJ as compared to baseline (from 9.2 ± 1.6 mm/s to 14.5 ± 2.4 mm/s). Its further significant ($p \leq 0.05$) increase was observed after jumps dropped to 50% of 1MJ (to 19.6 ± 2.6 mm/s). However, there was only slight increase in COP velocity after jumps dropped to 25% of 1MJ (to 21.4 ± 3.2 mm/s). **Conclusions.** Taking into account a gradual increase in sway velocity after jumps matched 75% and 50% of 1MJ and its no further increase after jumps matched 25% of 1MJ, it may be assumed that post-exercise balance impairment is not linearly related to the level of proprioceptive stimulation.

Key words: aerobics, jumps, postural sway, proprioceptive stimulation

Introduction

Landings are common part of the performance in sports, such as gymnastics, rock and roll, and aerobics. From biomechanical analyses it is known that ground reaction forces in aerobics may reach 3-, 4-, and even 5-times the body weight [1]. A substantially higher peak forces have been recorded in gymnasts' landing ranged from 8.2 to 11.6 times the body weight [2]. They often land with minimal flexion at the hip, knee, and ankle, which is a primary means of attenuating energy during landings [3, 4]. In addition, gymnasts expose higher ground reaction forces during drop landings from heights of 60 to 90 cm (40.3 N/kg and 56.0 N/kg, respectively) than recreational athletes (27.0 N/kg and 37.4 N/kg, respectively) [5].

It may be assumed that repetitive exposure to such high loads may contribute to the incidence of lower limb injuries. These injuries account for 50% [6] to 64% [7] of all injuries. Among those the most frequent site of trauma is the ankle [8], followed by the knee [9].

In particular, functional instability of the ankle joint is a later complication of 10% to 30% of acute ankle sprains [10]. Functional instability is associated with decreased strength of ankle musculature, impaired proprioception, loss of balance and ligamentous laxity [11]. Decades ago it was postulated [e.g., 12] that these injuries could result from delayed reflex responses to stress on ankle ligaments as a result of damage to ankle joint receptors at the time of initial injury. However, recent evidence [e.g., 13] suggests that dynamic control of ankle stability is achieved by feedforward mechanisms of the central nervous system rather than by means of feedback effected by peripheral reflexes.

Caulfield and Garrett [14] have documented that lateral and anterior force peaks occurred significantly earlier in subjects with functional instability of the ankle joint. Significant differences were seen between groups' time-averaged vertical, frontal and sagittal components of ground reaction force. These ranged from 5% (frontal force) to 100% (vertical force) of body mass. According to authors the disordered force patterns observed in subjects with functional instability are likely to result in repeated injury due to significant increase in stress on ankle joint structures during jump landing. They suggest that these injuries are, most likely, to result from deficit in feedforward control of ankle joint movement. This is important also for initiation of a vertical jump because of the human body's upward propulsion that has been found [15] to depend

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on control of forward equilibrium. Due to biomechanical constraints, balance is first lost through a backward center of pressure shift. The COP is then moved forward so as to reach a position favorable to produce a vertical jump.

However, intensive jumping may not only increase the risk of injuries but can also negatively affect the performance. More specifically, intensity of proprioceptive stimulation during jumps has been found [16] to significantly influence feedback mechanisms involved in balance control. Its effect depends not only on the type of exercise but likely also on height of the jumps and their duration. For instance, a greater postural sway was documented [16] after jumps than calf rises, both eliciting the same ventilation. Also more profound balance impairment has been found [17] after about 3-times higher maximal jumps than aerobic jumps, both eliciting the same ventilation.

However, there is no information of how duration of the jumps influences postural stability in aerobic dancers. Experience showed that in 1.45 min aerobic routine from 352 difficulty elements in total (balance, flexibility, static and dynamic strength) there is more than half – 182 jumps.

Therefore the aim of the study was to compare the parameters of balance after continuous CMJs eliciting different levels of proprioceptive stimulation determined by percentage of max height of the jump.

Material and methods

Subjects

A group of 11 female professional aerobic dancers (aged 17.8 ± 2.4 years, height 163.6 ± 5.2 cm, weight 55.3 ± 5.4 kg) volunteered to participate in the study. All of them were informed of the procedures and of the main purpose of the study.

Test protocol

Subjects underwent a 10-second test of maximal jumps with hands fixed on the hips. The mean of three max values of such a jumping series was considered as a max jump height (1MJ). For this purpose a diagnostic system FiTRO Jumper consisting of a special contact switch mattress connected by means of an interface to a computer was used. The system measures contact and flight times (with accuracy of 1 ms) during jumps and calculates basic biomechanical parameters (e.g., height of the jump).

After about 20 minutes subjects performed repeated jumps with maximal effort until the jump height dropped to 75%, 50%, and 25% of 1 max jump (1MJ), respectively achieved in non-fatigued conditions. The same system FiTRO Jumper was used to measure height of jumps. Landings were performed barefoot with the trial duration (determined by % of 1MJ) order randomized for each subject.

Thirty seconds prior to and two minutes immediately after the exercises the COP velocity was registered at 100 Hz by means of posturography system FiTRO Sway Check based on dynamometric platform. Average values of 5-second intervals were used for the evaluation. Subjects were instructed to minimize postural sway by standing as still as possible.

While exercising and standing on stabilographic platform a heart rate was continuously monitored using SportTester.

A subjective level of exertion was estimated immediately after cessation of each exercise using Borg's 6 to 20 Rating of Perceived Exertion Scale [18].

Statistical analysis

Ordinary statistical methods, including average and standard deviation, were used. A Wilcoxon test was employed to determine the statistical significance of differences between pre- and post-exercise parameters of balance, $p \leq 0.05$ was considered significant.

Results

It has been found (Fig. 1) that max height of the jump (MJ) decreased from 27.7 ± 2.8 cm to 20.1 ± 2.6 cm when subjects dropped to 75% of 1MJ, to 13.8 ± 1.6 cm at 50% of 1MJ, and to 6.9 ± 0.8 cm at 25% of 1MJ.

The COP velocity (Fig. 2) was significantly ($p \leq 0.01$) higher after jumps matched 75% of 1MJ as compared

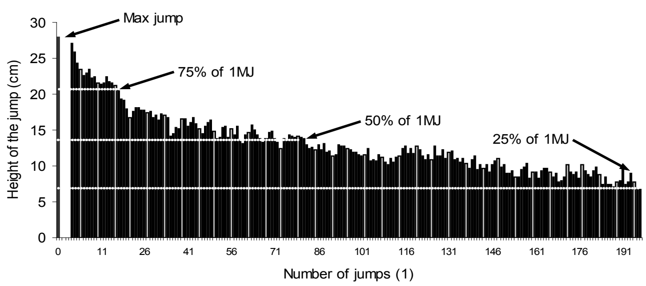

Figure 1. A schematic representation of the test execution: subjects performed three trials of repeated jumps with maximal effort until the jump height dropped to different percentages of 1MJ

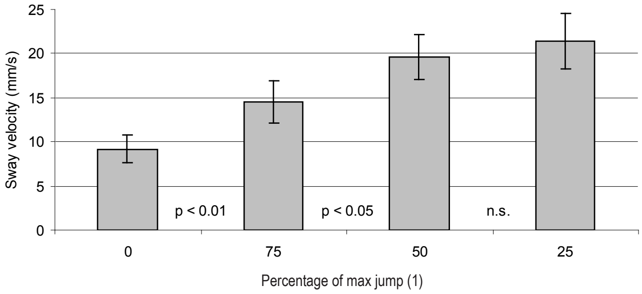

Figure 2. Sway velocity after jumps matched different percentages of 1MJ

to baseline (from 9.2 ± 1.6 mm/s to 14.5 ± 2.4 mm/s). Its further significant ($p \leq 0.05$) increase was observed after jumps matched 50% of 1MJ (to 19.6 ± 2.6 mm/s). However, there was only a slight increase in COP velocity after jumps matched 25% of 1MJ (to 21.4 ± 3.2 mm/s).

In this case, its values remained temporarily elevated with slight tendency to increase and only after about 15–20 seconds a gradual decrease back to the resting level set in. However, COP velocity did not return to pre-exercise level within 2 minutes of recovery. On the other hand, after jumps matched 50% and 75% of 1MJ sway velocity started to decrease within 5 seconds of recovery.

According to Borg' scale [18] subjects perceived jumps matched 75% of 1MJ as light (11) to somewhat hard (12), those at 50% of 1MJ as hard (14), and those at 25% of 1MJ as very hard (18). Because a rating of 20 is rarely given by subjects, the RPEs above 18 are considered as a strenuous exercise [19].

Discussion

Jumping performance of the subjects examined decreased to 75% of 1 max jump after about 17 jumps, to 50% of 1MJ after 81 jumps, and to 25% of 1MJ after 196 jumps. Such intensive proprioceptive stimulation during jumps seems to have an important influence on feedback mechanisms involved in control of balance, as indexed by an increase in sway velocity.

From biomechanical analyses it is known that ground reaction forces in aerobics may reach 3-, 4-, and even 5-times the body weight [1]. It may be assumed that stimulation of muscle spindles, tendon organs, joint receptors and cutaneous mechanoreceptors on the sole during jumping led to the impairment of their sensitivity. In particular, activity of muscle spindle can change under muscular fatigue [20, 21], possibly via modulation of reflex pathways originating from small-diameter muscle afferents, namely group III and IV afferents [22]. Resulting partial reduction of afferent impulses leading to deterioration in proprioceptive feedback control of balance after jumps matched 75% of 1MJ contributed to about 36.6% increase in sway velocity relative to pre-exercise values. Further 26% increase was observed after jumps matched 50% of 1MJ.

However, despite more than double duration between jumps performed to drop at 50% and 25% of 1 max jump, sway velocity only slightly increased (on average 8.4%). This may be ascribed to an increase in excitability threshold. In this case, also compensatory mechanisms, e.g. increased reflex activity in muscle spindles [20] or increased muscle stiffness due to fatigue can be used for postural control.

Similarly, Vuillerme et al. [23] found that under muscle fatigue vibration does not induce a further increase in postural sway. They suggest that, to some extent, under the condition of fatigue, the central nervous system may decrease the reliance on proprioceptive information from the ankles and may use other sensory inputs providing a more reliable information for regulating postural sway. More specifically, in the context of ankle muscle fatigue, it would be appropriate for the CNS to rely less on proprioceptive information from the ankles. As a result, the multisensory integration made by the CNS would force the subjects to use other sensory inputs providing more reliable information for the regulation of postural sway (e.g., vestibular, neck, hip and knee proprioceptive inputs).

In addition, the control and perception of ankle movement results from the co-processing of both agonist and antagonist muscle spindles activity. In other words, the CNS would rely mainly on contrasting agonist and antagonist sources of information.

These findings indicate that besides the proprioceptive information generated by the ankle dorsiflexors, there are other mechanisms able to control efficiently postural stability in fatigue. This may, in part, explain only a slight increase in sway velocity after more than double duration of jumps performed to drop at 25% of 1MJ than those matching 50% of 1MJ.

Besides an acute balance impairment after exercise, also its readjustment to pre-exercise level is considered as an important ability in sports like aerobics or gymnastics, where impaired balance resulting from intensive jumping may adversely affects performance. Time course of postural sway after jumps matched 25% of 1MJ showed transient increase followed by 15 to 20 seconds of plateau and only then a gradual decrease back to the resting level set in. On the other hand, its values after jumps matched 50% and 75% of 1MJ started to decrease within 5 seconds of recovery. Thus, in order to obtain more precise information on postural sway response to exercise, both magnitude of balance impairment in an initial phase of recovery and speed of its readjustment should be analysed.

Conclusions

Sway velocity is significantly higher after jumps performed to drop at 75% of 1 max jump when compared to pre-exercise level. Its further increase occurs after jumps matched 50% of 1MJ. This effect may be ascribed to the deterioration of proprioceptive feedback control of balance.

In spite of more than double duration of jumps matching 50% and 25% of 1MJ, there is only a slight increase in sway velocity. It means that there is no linear relationship between the post-exercise balance impairment and the level of proprioceptive stimulation.

However, further studies are needed to evaluate the effect of such a deterioration of balance after jumping on performance in aerobics.

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