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PERFORMANCE AND INTRALIMB COORDINATION DURING A CONTINUOUS VERTICAL JUMP TEST

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SUMMARY
This study analyzed modulation of jump performance and intralimb coordination throughout a 30 s vertical jump test. Twenty male athletes performed the test on a force plate while also undergoing kinematic analysis. Jump height and coordination by continuous relative phase (CRP) were analyzed. Results showed reduction of jump height during the test. No changes were observed in CRP for thigh-leg coupling when comparing initial to final jumps, but the trunk-thigh coupling was more in-phase near the end of the test. We conclude that fatigue causes reduction in jump performance and changes in intralimb coordination appear at the last 10% of the test.

INTRODUCTION
Continuous vertical jumps are often used in lower limb power training or in assessing anaerobic performance (e.g. Bosco Test). A common characteristic of such anaerobic tests is their short duration and high intensity, leading the athlete to develop muscle fatigue. Besides the influence of muscle strength parameters on maximal jump height achieved, actual performance depends also on motor control. There is evidence that some compensatory neuromotor mechanisms are used to counterbalance the loss of force-generating properties due to fatigue [1]. However, little is known about whether or how the neuromuscular system reorganizes segmental movement coordination under fatigue and its effects on performance parameters during a continuous jumps protocol. Thus, this study aimed to analyze the modulation of jump performance and intralimb coupling coordination throughout a maximal continuous vertical jump test. We expected that fatigue would occur during the test, decreasing jump performance and changing intralimb coordination at the end of the test.

METHODS
Twenty male athletes (16 volleyball and 4 basketball players; age 23.3 ± 3.6 years; body mass 81.7 ± 9.4 kg; height 184 ± 5.7 cm), volunteered to participate in this study.
The continuous 30-second vertical jump test was performed on a force plate (Quattro Jump, 9290AD, Kistler®, Winterthur, Switzerland) with sampling frequency of 500 Hz. Two dimensional kinematics were obtained during the test using a calibrated camera (VPC-HD2000 Xacti, Sanyo Electric Co., Japan) sampling at 60 Hz. A set of body landmarks were placed on the right side of the participant's body. The landmarks were semi-automatically digitized (SkillSpector - Video4coach, Denmark).
Ground reaction force data obtained during the continuous jump test were filtered using a low-pass 4th order Butterworth filter with cut-off frequency of 10 Hz. From the filtered data, jump height was obtained by double integration of force. The fatigue index (FI) was calculated as follows: jump height (first 10% of jumps) – jump height (last 10% of jumps) / jump height (last 10% of jumps).
Coordinates of the markers were filtered using a 4th -order Butterworth low-pass filter with cut-off frequency of 10 Hz. The segmental angles of the trunk, thigh and leg were determined for intralimb coupling coordination analysis. The continuous relative phase (CRP) analysis was used to assess intralimb motion coupling, a measure of coordination between segments [2]. In this analysis, the phase plot (angular position x angular velocity) for each segment motion was normalized in order to calculate phase angle (∅), comprising a range of 0 - 180°. CRP was calculated as the difference between the normalized phase angles of two segment motions only during the ground contact phase of the jump. In each coupling, the distal segment was subtracted from the proximal and was calculated between the thigh and trunk (trunk - thigh) and between the leg and thigh (thigh - leg). All analyses considered flexion/extension of the joints during ground contact of jump. CRP variability (CRP_V) was represented by standard deviation of the CRP measures of every point of the curve. The root mean square (RMS) was calculated for CRP and CRP_V to compare the values between initial and final of test.
Data were reported as means and standard deviations. Jump height and the RMS values of CRP and CRP_V were compared using a paired t-test between the initial (first 10%) and final jumps (last 10%) of the continuous jump test.

RESULTS AND DISCUSSION
The fatigue index obtained during the continuous jump test was 26.34 ± 5.05%. The fatiguing nature of the protocol was reflected by the decrease observed on jump height ($p = 0.01$) from the beginning (49.5 ± 6.02) to final (36.06 ± 5.1 cm) of continuous jump test.
Figure 1 shows the CRP and CRP_V curves for the trunk-thigh and thigh-leg segments for the first and last 10% of the continuous jump test. With respect to trunk-thigh coupling (figure 1 – A and B), there was no significant difference ($p = 0.56$) in the RMS values for the eccentric phase between the initial and final conditions. However, during the concentric phase the continuous relative phase decreased significantly

from the initial to final condition of the continuous jump test ($p = 0.04$), i.e., the trunk-thigh coupling was more in-phase at the end of exercise. Fatigue as a result of the continuous jumps test did not change the intralimb coordination of the thigh-leg (figure 1 – C and D) from the initial to final condition, in both the eccentric ($p = 0.69$) and concentric phases ($p = 0.97$).
With respect to CRP_V, significantly higher values in the final, compared to the initial jumps were observed for the trunk-thigh coupling in both phases ($p = 0.04$) as well as for the thigh-leg coupling in the concentric phase ($p = 0.04$). The continuous relative phase variability of the thigh-leg did not differ significantly in the eccentric phase ($p = 0.12$).

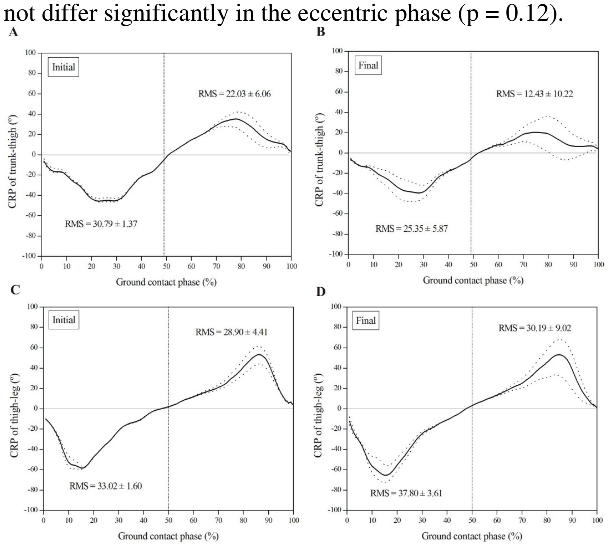

Figure 1. Continuous relative phase (M ± SD) of trunk-thigh (A and B) and thigh-leg (C and D) segment couplings in the initial and final of the continuous jump test.

Fatigue during the continuous jump test was well reflected in the parameters analyzed in the present study. According to our hypothesis, fatigue was also reflected by jump performance decreasing (i.e. jump height) throughout the test. The decline in the ability of the muscles to produce force is considered the major factor responsible for jump height decrease [3,4].
No change was observed in the CRP (RMS values) of thigh-leg coupling when comparing the initial and final of the continuous jump test. This shows that coordination between these segments was not affected by fatigue. The same result was observed for trunk-thigh coupling in the eccentric phase of the jumps. Our results are, in part, in agreement with Rodacki et al. [4], who also found no changes in lower limb coordination in the countermovement jump after a continuous jump task. The hypothesis proposed by Rodacki et al. [4] to explain these results is the existence of a pre-programmed stimulation pattern or a robust pattern, which guides movement execution by a fixed set of commands (neural input), irrespective of the changes imposed in the muscle force-generating properties [5].
However, we verified that trunk-thigh coupling in the concentric phase of jumps became more in-phase at the end of the continuous jump test therefore, showing changes in the coordination pattern under fatigue. This suggests the existence of compensatory mechanisms in which some segments are used to counterbalance the loss in the force-generating properties of the muscles due to fatigue, as hypothesized in our study. This adjustment in segmental motion may be due to proprioceptive stimuli generated by sensory receptors sent to the nervous system, indicating the presence of fatigue and thus demanding adjustment of the coordination pattern [6].
We observed higher continuous relative phase variability in the final (last 10%) compared to beginning (first 10%) part of the continuous jump test, indicating that under fatigue there is a greater fluctuation or instability, for all couplings. Variability in joint coupling has been suggested to play a major role in the aetiology of injury [2]. Thus, the variety of each coupling action in the fatigue condition would indicate that there were multiple combinations of coupling patterns that could be utilized and would be an optimal solution because it would mean that no soft tissue would be repeatedly stressed [2].

CONCLUSIONS

A 30-second continuous jump exercise is a task that induces fatigue. Reduction in jump performance was observed in the final of test. The coordination between thigh-leg segment coupling did not change under fatigue, but the trunk-thigh segment coupling became more in-phase at the end of the test (only the concentric phase of the jump). This provides some evidence of changes in the coordination pattern. The increase in the continuous relative phase variability during the final phase of the test indicates that under fatigue there was a greater variability in both the thigh-leg and trunk-thigh segment couplings.

REFERENCES

1. Bonnard M, Sirin AV, Thorstensson A. Different strategies to compensate for the effects of fatigue revealed by neuromuscular adaptation processes in humans. Neuroscience Letters, 166, 101-105, 1994.
2. Hamill J, Van Emmerik REA, Heiderscheit BC, Li L.. A dynamical systems approach to lower extremity running injuries. Clinical Biomechanics, 14, 297-308, 1999.
3. McNeal, JR, Sands WA, Stone MH. Effects of fatigue on kinetic and kinematic variables during a 60-second repeated jumps test. International Journal of Sports Physiology and Performance, 5, 218-229, 2010.
4. Rodacki ALF, Fowler NE, Bennett SJ. Multi-segment coordination: fatigue effects. Medicine and Science in Sports and Exercise, 33, 1157-1167, 2001.
5. Van Zandwijk JP, Bobbert MF, Munneke M, Pas P. Control of maximal and sub-maximal vertical jumps. Medicine and Science in Sports and Exercise, 32, 477–485, 2000.
6. Kurz MJ, Stergiou N, Buzzi UH, Georgoulis AD. The effect of anterior cruciate ligament reconstruction on lower extremity relative phase dynamics during walking and running. Knee Surgery, Sports Traumatology, Arthroscopy, 13, 107-115, 2005.