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Analysis of the Influence of a Triple Jump Contest on the Equilibration Function

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Abstract

The aim of the study was to investigate, during a triple jump event, the positive or negative impact of the repetitive task on the postural stability that triple jump performance depends. Fourteen triple jumpers were recorded before the warm up and just after cessation of triple jump contest, on standardizing foot position according to Standard AFP 85 with a stabilometric coupled single-foot platforms (Cyber-Sabots®, Marseille, France). The test consisted of two conditions (Pre-event and Post-event), each consisting of 51.2-s trials. At the end of the triple jump event, attendees have significantly reduced the lenght of the statokinesigram (p=0,016<0,05), the ratio of the statokinesigram length, the Mean speed (p=0,013<0,05) and the total energy of postural sways of the vertical plan (p=0,009<0,05). Our study suggests that a positive modification on postural stability in standing position seems to be providing by a repetitive exercise soliciting the maximal muscular power output. Following these results, a study focus on the lower limb muscles could be relevant to identify and analyze more precisely the mechanisms for control the postural stability after a triple jump event.

Keywords : *Triple jump, equilibration, body balance, repetitive task.*

Introduction

The triple jump is an athletic event that requests specifically a great body balance in order to optimize the performance. It consists of maximazing a running approach followed by a hop (take off from one foot and landing on the same foot), a step (take off from one foot and landing onto the opposite foot) and a jump in the sand [1]. Several biomechanical analysis of triple jump has been conducted by comparing different jumping techniques [2], by assessing effort distribution [3,4] or by measuring velocity approach[5,6]. Accordingly, the triple jump requires that the athlete exert a perfect control of his body balance [1]. In this way, many studies showed that fatiguing physical exercises induced a global postural instability that may result a deficient technical movement [7]. According to Nardone et al. [8], the effects of the fatigue depend on the intensity of the physical activity: strenuous exercises increased body sways whereas light exercises were able to decrease body sways. Physical fatigue leads to perturb the regulation of the body balance.

However, it was also noted that repetition of the same task, as triple jump trials, led to a motor performance optimization in order to reduce body sways [9]. According to Lord et al. [10], exercise can produce an improvement in the sensorimotor function of the individual. More precisely, balancing exercises improve proprioception. The optimal equilibrium function of the athletes results from repeated actions or movements that influence the motor response and especially proprioception. Elite athlete training improve equilibration performance through neurological adaptations by decreasing the role of the visual system in favor of the proprioceptive system [11]. Physical exercise increases muscle strenght and the velocity of muscle contraction [12], increases muscle stiffness [13], and modifies postural strategies by developing the capacity to quickly replace the use of a sensory reference to another, or to preferentially reinforce a sensory reference [14].

The purpose of this study was to investigate, during a triple jump event, the impact of arepetitive task on the body balance in standing position. We proposed to test the positive or negative impact of the repetitive task on the postural stability that triple jump performance depends.

Materials and Method

Subjects

Nine triple jumpers male and five triple jumpers female volunteered for this study. They all had training experience in high level competitive triple jumping, healthy, free of pathology to perform a triple jump event.Participants presented mean ± standard deviation height 176 ±7 cm, body mass 67.6 ± 10 kg, foot size was 42.4 ± 2.4 and age 24 ± 5 years. This experiment was accepted by the local ethical committee.

Procedure

The subjects were recorded during the French Elite Athletic Championship in Villeneuve d'Ascq (10-12 July 2015). Attendees were recorded in accordance with both a standardizing foot position according to Standard AFP 85 and the Clinical Stabilometry Standardization of the International Society of Posture and Gait Research (ISPGR) to determine clinical parameters and sampling frequency [15].All tests were performed before the warm up and just after cessation of triple jump contest. The test consisted of two conditions (Pre-event and Post-event), each consisting of 51.2-s trials [16,17,18]. The test was conducted in the following order: upright standing, barefoot on the platform before the triple jump event (S1) and upright standing, barefoot after the triple jump event (S2). Subjects were instructed to maintain the head, arms and hips in a steady position [16,19,20]. The foot positions were marked on force platform for every participant and were the same for all trials.

Stabilometric Measurements

A stabilometric coupled single-foot platforms (Cyber-Sabots ®, Marseille, France) was used to provide automatic measurements of the forces applied to the floor by an individual standing upright and to determine the general pattern of force distribution in relation to specific position inside a supporting polygon defined by plantar contact area.Cyber-Sabots are destined for designing systems to evaluate and rehabilitate postural abnormalities and to evaluate posture for sports activities. Interpretation of center of pression (CoP) and excursion data obtained from bipedal force platforms can provide important insight into posture asymmetry and quality of posture control [21]. Machined from a solid block of aviation aluminium (AU4G), Cyber-Sabots feature mechanical qualities including rigidity and lightness (1.3 kg) and are characterized by reduced thermal constraints and hysteresis. Forces were sampled at 40 Hz.Stabilometry allows, from a clinical perspective, to represent the movement of the CoP. This representation determines both the "performance" parameters needed to understand the management of static equilibration but also the "strategy" parameters that reveal the individual's own capacities in the motor control of his equilibrium [22]. More specifically, the performance indicators provide information on the quality of postural control, while the strategy indicators allow us to appreciate how the subject puts in place the control of movement variations of the CoP.

Five performance parameters were selected to evaluate the energy expended by the subject to maintain a standing balance: Lenght (L, mm) of the statokinesigram, Surface area (S, mm^2) of the statokinesigram, the ratio of the statokinesigramlenght and its surface (LFS), Mean Speed of the CoP (MS, $mm.s^{-1}$) and Variance of Speed (VS).

Strategy parameters consist on a spectral analysis that account for the preferential activation of regulation loops by an individual to ensure his balance in the three planes of space: frontal plane (Wx), sagittal plane (Wy) and vertical plane (Wz).

All these variables express the CoP behavior whereby an increase in the variables mean an increase on instability [23].

Data Analysis

All data were analysed using Statistica 12 (Statsoft, France) software. We compared the participants' performance under two conditions (S1 and S2) and according to the experimental hypothesis that the realization of a tripe jumping competition influences the quality and the control of the standing position in the direction of an optimization of the equilibration function. We therefore performed an intra-subject analysis by repeating measurements on the independent variable (lack of repetition (Pre-Event)/ presence of jumps (Post-Event)) under two conditions. Given the low distribution studied (n = 14) and the strong dispersion around the central value observed during the descriptive analysis, we decided to perform non-parametric tests, including the Wilcoxon test, to test the statistical significance of the difference between the scores obtained respectively under the two experimental conditions.Statistical significance was set at $p<0.05$ Results were expressed as mean ± standard deviation for all postural descriptors.

Results

Performance parameters (mean ± SD; median) and significant difference between Pre-Event and Post-Event are reported in Table 1. In Pre-Event condition, Lenght, Surface area, LFS, Mean Speed and Variance of Speed of CoP were respectively 555 mm ± 169.7; 549 (mean ± SD; median), 243 mm^2 ± 107.1; 224, 1.14 ± 0.30; 1.10, 10.86 $mm.s^{-1}$ ± 3.28; 10.72 and 54.69 ± 37.14; 50 versus 464 mm ± 108.2; 428, 207 mm^2 ± 105; 184, 0.98 ± 0.19; 0.94, 9.06 $mm.s^{-1}$ ± 2.11; 8.35 and 38.1 ± 19.57; 30 in Post-Event condition.

Strategy parameters (mean ± SD; median) and significant difference between Pre-Event and

Post-Event are reported in Table 2. Spectral analysis on the frontal plane, sagittal plane and vertical plane were respectively 17.86 ± 7.47; 17 (mean ± SD; median), 23.21 ± 8.61; 21.5 and 50.78 ± 27.23; 48.5 in Pre-Event condition versus 15.78 ± 4.42; 16, 20.36 ± 6.16; 18.5 and 39.57 ± 12.52; 43in Post-Event condition.

Table 1. *Performance parameters (mean ± SD; median) for Pre-Event and Post-Event. Lenght (L) and surface area (S) of the statokinesigram, the ratio (LFS) of the statokinesigram length and its surface area, Mean Speed (AS) and variance of Speed (VS) are presented.*

	Pre-Event	**Post-Event**
L (mm)	555 ± 169.7 ; 549	464 ± 108.2; 428 *
S (mm^2)	243 ± 107.1 ; 224	207 ± 105; 184
LFS	1.14 ± 0.30 ; 1.10	0.98 ± 0.19; 0.94 *
MS ($mm.s^{-1}$)	10.86 ± 3.28 ; 10.72	9.06 ± 2.11; 8.35 *
VS ($mm^2.s^{-2}$)	54.69 ± 37.14; 50	38.1 ± 19.57; 30

** p < 0.05*

Table 2. *Strategy postural parameters (mean ± SD; median) for Pre-Event and Post-Event. Spectral analysis on the frontal plane (Wx), sagittal plane (Wy) and vertical plane (Wz) are presented.*

	Pre-Event	Post-Event
Wx (Hz)	17.86 ± 7.47 ; 17	15.78 ± 4.42 ; 16
Wy (Hz)	23.21 ± 8.61 ; 21.5	20.36 ± 6.16 ; 18.5
Wz (Hz)	50.78 ± 27.23 ; 48.5	39.57 ± 12.52 ; 43 *

** p < 0.05*

Spectral analysis (mean ± SD; median) on the vertical plane according to the different frequency bands (0-0.5 Hz, 0.5-2 Hz et 2-20 Hz) and significant difference between Pre-Event and Post-Event are presented on the table **3**. Low frequencies (0-0.5 Hz), medium frequencies (0.5-2 Hz) and hight frequencies (2-20 Hz) were respectively 5.71 ± 3.31; 5.5, 5.14 ± 6.41; 4 and 40.21 ± 17.28; 37.5 in Pre-Event condition versus 5.07 ± 1.97; 5, 3.51 ± 2.59; 3 and 33.21 ± 8.47; 32 in Post-Event condition.

Table 3. *Strategy parameters (mean ± SD; median) for Pre-Event and Post-Event. Spectral analysis on the vertical plane (Wz) according to the different frequency bands (0-0.5 Hz, 0.5-2 Hz et 2-20 Hz) are presented.*

	Pre-Event	Post-Event
Wz (0-0.5 Hz)	5.71 ± 3.31 ; 5.5	5.07 ± 1.97 ; 5
Wz (0.5-2 Hz)	5.14 ± 6.41 ; 4	3.51 ± 2.59 ; 3
Wz (2-20 Hz)	40.21 ± 17.28 ; 37.5	33.21 ± 8.47 ; 32 *

** $p < 0.05$*

Discussion

From a descriptive point of view, the results display a decrease between Pre-Event condition and Post-Event condition of all postural variables. The standard deviations of all the variables also decreased which shows a decrease in the variability.

From a statistical point of view, the results showed that the triple jump practice resulted in a significant reduction in both the performance parameters (L, LFS, MS) and the strategy parameters such as the total energy of postural sways of the vertical plane (Wz) and specifically the frequency band of 2 to 20 Hz.

This study builds on earlier work that has shown, concerning to the effects of physical activity on the human standing balance [8,24,25]. More precisely, our study display that the practice of triple jump does not lead to sufficient muscular fatigue to degrade the equilibration function. On the contrary, the triple jump practice causes a positive modification in the quality and control of the postural balance.

The Quality of Equilibration

In the triple jump context, the quality of the equilibration indicates the postural performance. This quality depends on the physical intensity of the discipline and the type of exercise to be performed.

First of all, our study shows that the triple jump is presented as a discipline leading to a weak muscular fatigue. According to Enoka's definition [26], muscle fatigue is associated with a reduction in the force of contraction that can degrade postural balance. This is an extension of the study by Nardone et al. [8] who showed that a discipline, when performed below the anaerobic threshold, has negligible effects on the equilibration function. In this context, muscular fatigue is not important enough to degrade the quality of postural equilibration. However, this lack of intense fatigue is not a factor to improve this quality of equilibration.

Then, learning the discipline of the triple jump requires a repetition of movements to apprehend and master a specific technical gesture. Such a repetition of movements of the same task appears as a factor of improvement of the quality of the equilibration. Indeed, according to the study of Tarantola et al. [9] the repetition of a task generally develops gesture learning. This is true in the triple jump since the repeated gesture in the training favors the control of the balance and thus improves the equilibration function.

Such an improvement can be explained by the fact that the training of the athlete in the control of his sporting gesture develops functional capacities of the musculoskeletal system [12] and thus improves his level of performance.

In addition, this development of the functional capabilities of the musculoskeletal system makes it possible to obtain muscular stiffness of the lower limb and thus a better stability.

Our study shows, indirectly, an improvement in stiffness by the significant decrease in postural sways as shown by the postural variables Length, Mean Speed of the CoP and LFS exposed above. Thus, the factor of improvement of the quality of the equilibration has its origin in the perseverance of the athlete to constantly repeat in training a technical gesture [27,28]. This repetition leads to an optimization of the muscular capacities of the locomotor apparatus, and in particular an improvement of the muscular stiffness. However, the intensity of the discipline does not cause enough fatigue to degrade the quality of equilibration.

The Control of Equilibration

The control of equilibration indicates the postural strategy implemented by the individual in order to regulate his balance. This requires a neurosensory adaptation that depends on constant learning through the athlete's training. The more the latter trains, the more the sensorimotor function of the individual becomes refined, and in particular the proprioceptive system [10]. The improvement of the equilibration function can lead to a neurological adaptation of a specific action, such as the triple jump, at the spinal and supra-spinal level [13]. This adaptation can lead to a reduction in the excitability of the spinal reflex, which has the consequence of inhibiting the muscular stretching reflex, thus making it possible to increase the muscular stiffness. Associated with this phenomenon of learning, the nervous system presents a "plasticity" allowing the preferential use of a sensory system dependent on the task to be performed [14]. Indeed, this nerve plasticity influences the improvement of equilibrium performances in athletes by decreasing the share of the visual system while increasing the other systems and in particular the proprioceptive system [29]. In other words, athletes have better accessibility to the proprioceptive sensorial reference that is to say that sensory tactile information coming from the plantar support and proprioception is more "sensitive" than the other sensory modalities [29]. Vaugoyeau et al. [31] even evoke a "predominance" of the proprioceptive system in the control of postural orientation in relation to visual and vestibular systems. In this sense, the study of Kean et al. [32] showed that proprioception training increased activation of the right femoral muscle while receiving a jump. This better activation would optimize the musculotendinous and articular stiffness reducing the damping phase of the support cycle and consequently improve the performance.

By stimulating the proprioceptive system, the motor response is improved. The good balancing function of elite athletes results from repeated actions or movements that influence the motor response through proprioception [33]. Our study confirms this point since we find a significant decrease in postural oscillations of the frequency band of 2 to 20 Hz of the vertical plane which accounts for regulatory loops from cutaneous and proprioceptive afferences. From all this, it follows that the control of equilibration is directly related to the biomechanical needs of the technical gesture for its optimization. Indeed, the use of proprioceptive system promotes muscle stiffness to struggle against crushing of the ground support. This requires muscle stiffness improving the stability and speed of support, while reducing the contact of the support including during the jump.

Conclusion

The main finding of the current study shows that the triple jump is presented as a discipline leading to a weak muscular fatigue. Repetition of movements of the same task appears as a factor of improvement of both the quality and the control of the equilibration.

Therefore, our study suggests thata positive modification onpostural stability in standing position seems to be providing by a repetitive exercise soliciting the maximal muscular power output. Following these results, a study focus on the lower limb muscles could be relevant to identify and analyze more precisely the mechanisms for control the postural stability after a triple jump event.

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