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Original Article

Biomechanical analysis of a rhythmic gymnastics jump performed using two run-up techniques

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Abstract
Theaim of this study is to describe the split leap performed using two types of run-ups. The first technique is a simple run (RT), and the second technique is the chassè (CT). The research was carried out through the kinematic analysis of the jump. The sample consisted ofa one 12-year-old gymnast (category A4) practicing rhythmic gymnastics at a competitive level for 4 years. A passive marker optoelectronic system, consisting of six BTS Smart-D cameras, was used for the kinematic analysis. In addition, two BTS Vixta cameras were used for the video support. Moreover, two force platforms were used to detect the contact and take-off.The CAST protocol was used for the acquisition and evaluation of the data. For each technique, the gymnast performed six trials. Data processing was performed by the Smart Analyzer software. The motor task was divided into three phases: run-up, take-off, and flight phases.Forthe three phases, the position, speed, and linear acceleration of the sacrum were examined.During the take-off and flight phases, speed and angular acceleration of the thigh segmentwere analyzed.During the flight phase, the amplitude of the splitwas observed.On the basis ofthe obtainedresults, it is clear that during the run-up and take-off phases, the height of the sacrum is greater using RT, but the maximum elevation is higher using CT during the flight phase. Regarding the speed, the horizontal component is higher using RT while the vertical component is higher in CT. The angle of flexion-extension of the splits is higher in CT. From the three-dimensionality of the movement in the hip joint during the split,it is clearthat in addition to flexion-extension, abduction and external rotation also occurred. Using CT, at the time of contact and shortly after take-off,angular acceleration during the flexion of the legregistered higher values. Therefore, it is assumed that limb momentum is more important when using CT than RT.Thus, it is assumed that the technical-coordinative elementacquired through the rhythmic gymnastics workouts, which occurs in chassè, considerably affects the efficacy of execution of the split leap. Thus, the use of descriptive analysis is essential to understand the kinematics of sports movement and is fundamental to structure training.
Key Words:rhythmic gymnastics, kinematic analysis, training, run-up techniques, enjambè.

Introduction

The rhythmic gymnastics is an exclusively female Olympic sport that involves performing exercises with musical accompaniment. The typical gymnastics elements must highlight the characteristics of flexibility, strength, coordination and power [1-2]. In addition, special requests are morphological and physiological characteristics [3]. The construction period of the race involves the insertion of "difficult". There are four components of difficulty: Body Difficulty (BD), dance steps combination (S), dynamic elements with rotation (R), apparatus difficulty (AD). BD's elements are the elements of the table difficulty in the Code of Points approved by FIG (International Federation of Gymnastics), divided into three groups: balances, rotations and jumps/leaps [4].

The study focuses on jumping elements and, specifically, about enjambè (sagittal split in flight).All the difficulties of jump must have some basic characteristics: fixed and definite form during the flight and height (elevation) of the jump sufficient to achieve the corresponding shape.

Current studies in the literature are investigating various aspects of the jump. Video analysis was performed to compare the split leaps jump and split leaps jump with trunk bent back [5]. Another study evaluated the degree of knee flexion in the loading phase in relation to jumping performance with a split [6].
The study conducted by Cicchella A. (2009) compared four different jumps through kinematic analysis of four parameters: last stride length (LS), knee loading angle previous to jump (KL), push time (PD) and flight time (FT) [7]. Another study conducted attheUniversidade do Porto compared four different jumps through kinematic analysis of: the different kinematics parameters observed were: duration of the take-off, flight phase and total time of the jumps; horizontal distance traveled; height of the center of mass (CM) at take-off, highest point, and the total height of the jumps; linear velocity of CM at take-off (horizontal, vertical and resultant); angle of outlet

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at take-off; angle of maximal removal of lower legs during the flight phase; trunk/thigh angle at the highest point of the jump and finally the minimal trunk/thigh angle reached during the flight phase [8].The study conducted by Purenović, T. et al. (2010) has seen the trajectory of the center of mass, the speed X and Y, and their resulting [9]. The splits leap was compared with a subjective evaluation by an experienced referee who ranked the gymnast's skill. The execution of the splits leaps was quantified by measuring ground reaction forces, electromyographic activity in the leg muscles and by analyzing film [10].

However, they were compared different jumps made with the same run-up technique. Therefore, it was decided to conduct a pilot study that took into consideration the same leap made with different run techniques.

In this regard, the aim of this study is the kinematic analysis of split leap with two run-up techniques to detect and describe kinematic differences.

The first technique consists of a simple run (RT) that does not require a technical effort, as it represents a basic scheme already acquired in earlier stages of development. The second technique consists in achassè (CT) which, on the contrary, requires a good technical-coordinative ability.

In function of the objectives of the research it was decided to pay particular attention to data related to amplitude variables, elevation, time and speed.

Were used a passive marker optoelectronic system, consisting insix cameras, BTS Smart-D for the kinematic analysis,two cameras BTS Vixta for a video support, two force platforms BTS P-6000 .
For the selection of the sample were evaluated three twenty years old agonistic gymnasts who take part in the individual championships and team gold sector of the Italian Gymnastics Federation (FGI). For each technique were carried outsix acquisitions. To proceed with the data analysis, it was decided to choose the gymnast who presented greater stability in the execution of the tests according to a referee evaluation by video analysis.

In split leap, kinematicevaluation can be used to provide considerable contribution trough quantitative data, highly accurate, on determining variables for the purpose of an objective evaluation of the movement. Therefore, thanks to the obtained data, is possible to make any technical adjustments, where necessary.

Objective

Theaim of this study is to provide a quantitative description of the main kinematic parameters of the split leap performedusing two types of run-ups. The objective, in particular, is to make a comparison and highlight any differences between the two techniques.

Material & methods

Participants

The sample consisted in one twelve years old gymnast practicing rhythmic gymnastics at a competitive level since she was four years old. She takes part in the individual and group gold competition of the Italian Gymnastics Federation (FGI).

Instruments

Were used a passive marker optoelectronic system, consisting in six cameras BTS Smart-D, for the kinematic analysis, three frontallyand three posteriorly to the acquisition volume. In addition,were used two cameras BTS Vixta for a video support, a mail frontally and the other sagittally to motor task.Moreover, were used two force platforms to detect the contact and take-off.

Acquisition Protocol

To proceed with the data acquisitions is necessary to prepare the environment and the subject. The environment preparation procedure consists in the calibration of the system through an axes sequence, where the laboratory reference triad is positioned at the center of the acquisition volume so that cameras have an origin and the axes to which to refer; and a wand sequence during which an axis is moved inside the capture volume to identify the boundaries of the working volume and facilitate the recognition of the markers by the cameras during the subsequent dynamic acquisitions. As regards the preparation of the subject,has been applied passive markers in specific anatomical landmarks. Were used seven markers: one positioned on the sacred and, for each leg, one on the trochanter, one on the medial condyle and one on the lateral condyle. In addition, two clusters [11], composed of four markers, were positioned on the thigh.

Before the execution of the motor task was carried out a warmup by gymnasts [12]. Warm up included exercises for flexibility in the lower limbs and hip through static and dynamic stretching.
It was carried out static acquisition. After, the markers on trochanter and condyles have been removed and the dynamics acquisitions of the jumpwas carried out. For each technique the gymnastshave performed six trials. Despite in rhythmic gymnastics the BD are performed mainly with apparatus (rope, hoop, ball, clubs, ribbon), in this study it was preferred to proceed with free-body acquisitions, because it seems gymnasts did not perform a jump with apparatus the best way that could[13].

Data processing protocol

Data processing was performed with the Smart Analyzer software. In the first place, the motor task has been divided into three phases: run-up, take-off, flight phase. The run-up phase analyzed ranges from 0.4 sec before the contact until the contact eventand includes the last step because it is considered more representative of this phase. The take-off phase goes from the contact event until take-off event. The flight phase goes from take-off to landing. The landing is identified with the event in which the sacrum reaches the same height recorded at take-off. The contact event and the take-off event were detected thanks toinformation provided by the force platforms. In all three phases were examined the position, speed and linear acceleration of the sacrum. Speed and linear acceleration were derived from the displacement. In the take-off and flight phases were analyzed also the parameters of speed and angular acceleration of the thigh segment. Speed and angular acceleration were derived by angular displacement of the reference systems of each thigh on all three axes, obtaining data relating to adduction-abduction, intra-extra rotation and flexion-extension. In the flight phase were observed the amplitude of split, calculated as the angle between the reference systems built on the thighs and the reference system of the motor task, which is fixed. The reference system on the thighs was built from a vector aligned with femur.

All parameters were reported to the reference frame of the motor task, aligned with the direction of the jump. To compare the trials, both intra-subject and inter-subject, a temporal normalization was carried out around the contact event. The cycle starts 0.4 sec before contact and ends with the landing, in this way, the phases determinants for the purposes of the analysis kinematics of the motor task, were included.

Cast protocol.

For the acquisition and processing was used the CAST protocol (calibrated anatomical system technique). This protocol consists in the application of cluster of, at least, three markers not aligned. If we consider a rigid body with a local reference system integral with its, the position of all the points belonging to the body does not vary, with respect to such reference, over time. In this way, given a reference system fixed to the bone segment in question, consisting of the cluster, we proceed with a first static acquisition of points taken into consideration. As a result, it is possible to remove the marker, leaving only the cluster during the dynamic acquisition and reconstruct, via software, the location of all the high points instant by instant [14].

Results

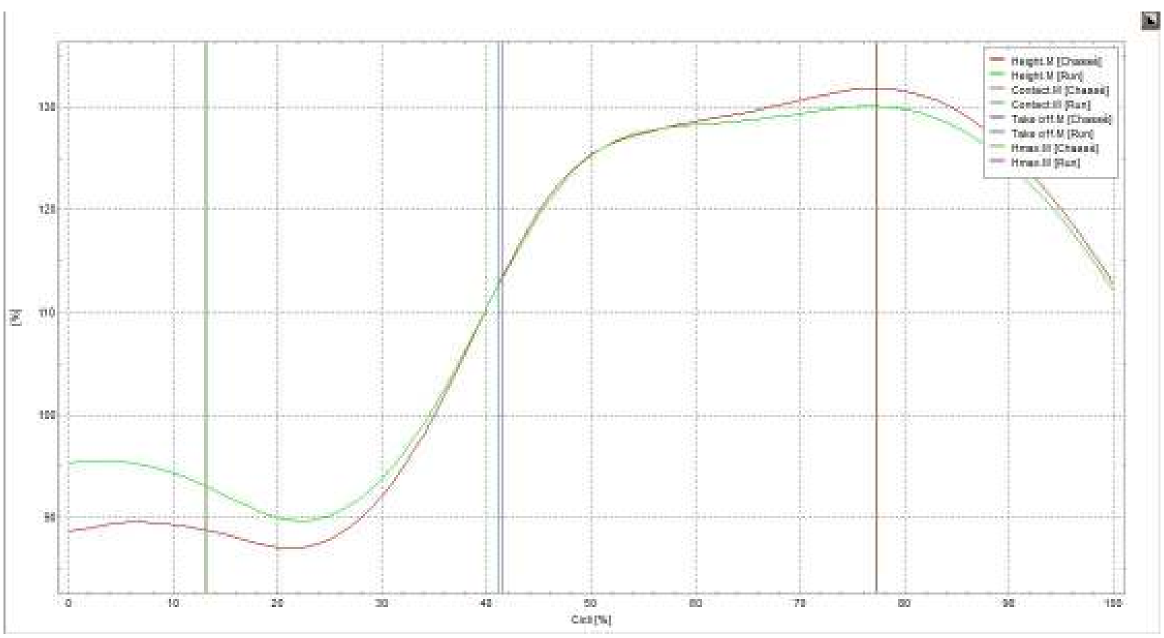

Fig.1.1. Height of the sacrum normalized as a percentage of the height of the sacrum in upright RT (green) and CT (red).

As it can be seen from the figure 1.1, in the run-up phase, the peak height of the sacrum in RT was reached to 4% of the cycle and is equal to 95% of the maximum height of the sacrum. In CT the peak is reached to 7% of the cycle and is the 89% of the height in the upright position.

With regard to take-off phase, the contact (13% of the cycle) in the RT is 93% in the CT is 88%; the minimum height of the sacrum is reached in both cases to 22% of the cycle, the RT is 89% and in the CT is 87%. At take-off (41% of the cycle) was recorded the same value of 113%. In the flight phase were observed two peaks: the first peak (55% of the cycle) the percentage value is equal to 127% in the RT and 127% in the CT; in the second peak (77% of the cycle) was 130% in the RT and 132% in the CT.

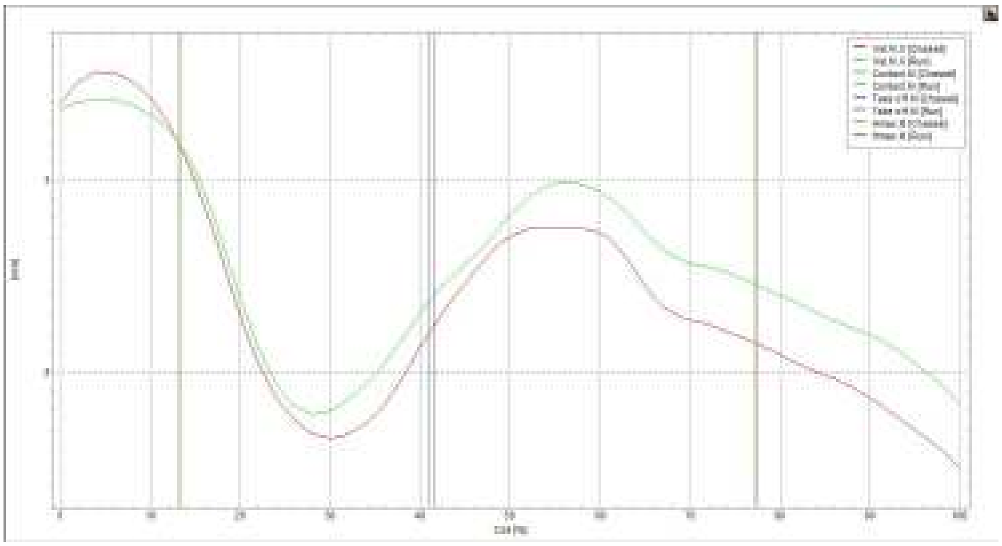

Fig. 1.2. Horizontal speed of the sacrum RT (green) and CT (red).

In the run-up phase (4-5% of the cycle) thehorizontal speed was 3.5 m / s in the CT and 3.4 m / s in the RT. At contact (13% of the cycle) was recorded a value of 3.19 m / s in both techniques. The minimum speed was recorded in the CT to 29% of the cycle and was 1.7 m / s while in RT the minimum wasrecorded around 28% and was 1.8 m / s. At take-off (41% of the cycle) in the CT was 2.2 m / s and in the RT was 2.3 m / s. During the flight phase, the peak was recorded at 53% of the cycle in CT and was 2.7 m / s and 56% of the cycle in RT and was 3 m / s. Subsequently, the speed decreased up to reach values of 1.5 m / s in the CT and 1.8 m / s in the RT, at landing (100% of the cycle) (fig.1.2).

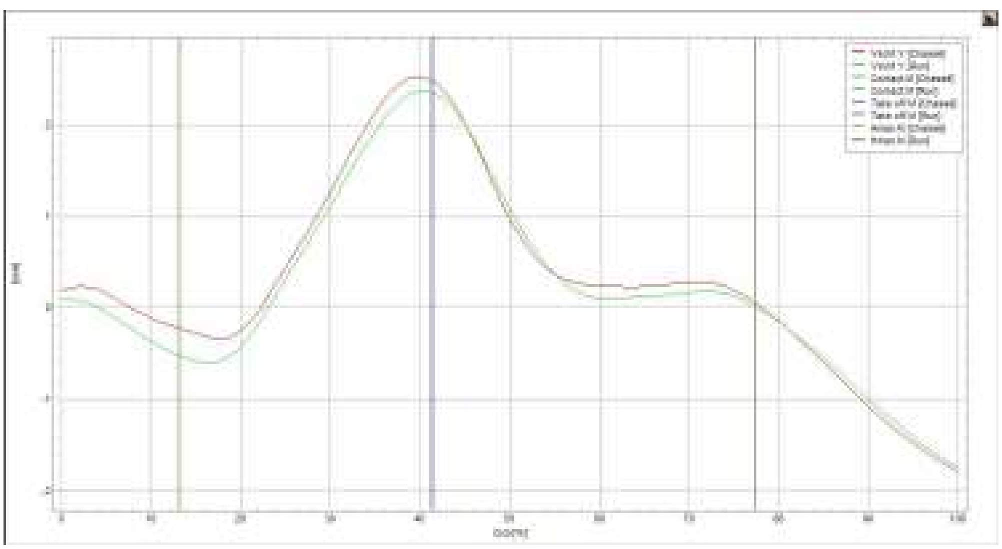

Fig. 1.3. Vertical Speed of sacrum RT(green) and CT (red).

The vertical speed at run-up phase (2% of the cycle) was 0.2 m / s in CT and 0.1 m / s in RT. At contact (13% of the cycle) was recorded a value of -0.2 m / s in CT and -0.5 in RT. The minimum speed was recorded in CT at 17% of the cycle and was -0.3 m / s, while in RT the minimum was recorded around 16% and was -0.5 m / s. At take-off (41% duty cycle) in CT was 2.5 m / s and in RT was 2.4 m / s. During the flight phase, in both techniques, the speed decreased rapidly up to 55% of the cycle, where it stabilized around the value of 0.2 m / s up to 77% of the cycle. Subsequently continued to decline slowly until landing (100% of the cycle) (fig. 1.3).

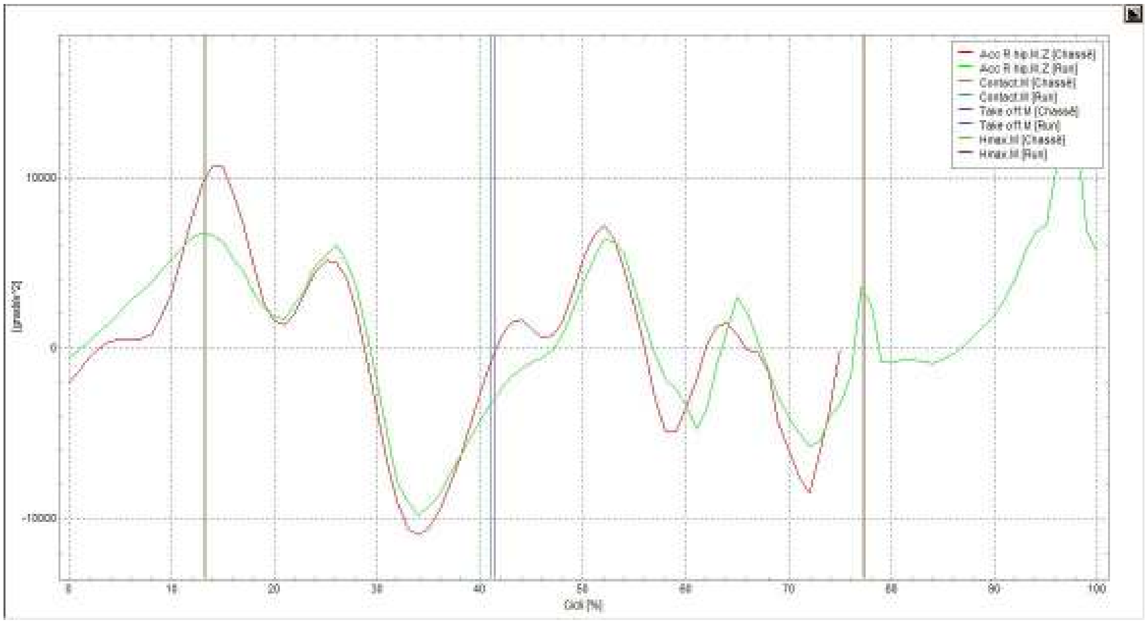

Fig. 1.4 Angular acceleration of right leg in flexion-extensionRT(green) CT (red).

In CT, at contact (13% of the cycle), the angular acceleration value was 9800 degrees / s2, but the peak was reached shortly after (14% of the cycle) and was 10650 degrees / s2. In RT the peak was recorded at contact and was 6740 degrees / s2. Another difference was found shortly after the take-off becausein CT there are two peaks. The first peak (44% of the cycle) was 1600 degrees / s2 and the second peak (52% of the cycle) was 7200 degrees / s2. In RT, however, was recorded only one peak at 52% of the cycle and was 6350 degrees / s2 (fig.1.4).

Discussion and conclusions

Based on the results obtainedin kinematic analysis of the jump, it can be stated that the height of the sacrum in the run-up phase and take-off is greater in RT, but the maximum elevation is reached with CT in the flight phase. The speed, in particular,thehorizontal component shows higher values in RT while the vertical component in the CT. The angle of flexion-extension of the splits is higher in CT. It is evident the three-dimensionality of the movement in the hip joint during the split, where in addition to flexion-extension occur abduction and external rotation [[15]]. About angular acceleration during flexion of the leg, in CT, at the time of contact and shortly after take-off, they are registered higher values. It is assumed, therefore, that in the CT limb momentum plays a greater role than RT.

It would be interesting to investigate this aspect through further investigation on a wider sample of gymnasts, differentiated with respect to the technical level. This may allow to strengthen these assumptions relating to the increased effectiveness of a run than the other, depending on the level of technical mastery achieved.

RT, in fact, is the first approach that the gymnasts, at the beginning, learn to perform the jumps; being a basic pattern already experienced and acquired in earlier stages of development, it allows the young gymnast to concentrate exclusively on the body shape during the jump.

It is assumed, therefore, that the technical-coordinative element, acquired with the rhythmic gymnastics' workouts, that occurs in chassè, have a considerable weight in the efficacy of execution of the split leap.

On the other side, understanding through descriptive analysis the kinematics of a sports movement is fundamental to structure training.

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