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## Analysis and application of gravity center leading technique in latin dance based on biomechanics

YuYuan Xu

Jining Medical University, Jining 272067, Shandong, (CHINA)

E-mail: tiyuxi@qq.com

### ABSTRACT

Latin dance is a partner dance, in which how the leader leads the follower influences the fluency and cooperation of the dance. This paper, by giving an analysis on biomechanics theories, states that the efficient leading between two partners should be realized by reasonable movement of the barycenter line. By analyzing barycenter leading technique, the paper presents a clear explanation on permission leading, limb leading and hint leading. Research shows that in partner dance, the man should be the leading part while the woman cooperates with him; leading only by arm often results in loss of balance of the lead or the partner; when one is leading with longer steps, postures of two dancers are often inconsistent; leading by the barycenter of the body can effectively avoid losing balance and provide a fluent and coordinate dance; this paper also points out that a good leading is virtually the passing process of the momentum of the body barycenter. This paper does away with old methods used to study Latin dance, which are artistically and aesthetical. It analyzes the leading techniques in Latin dance by biomechanics theories in a natural science perspective while proving the correctness of the dance and provides suggestions. © 2013 Trade Science Inc. - INDIA

### KEYWORDS

Barycenter line;  
Sole force point;  
Dance partner;  
Leading.

### INTRODUCTION

Latin dance originates from artistic dance in Africa and Latin America. It features passionate and quick-tempo music and versatile dance steps, and is largely popular as it is pleasant to watch. Most movements in Latin dance are done by waist, abdomen and crotch, which enable one's figure to be displayed. To a very large extent, the Latin dance is determined by dancer's will and improvisation, thus it is a great way to ease the pressure and tension resulted from modern life. It can

also exercise the body and revive one's spirit. Latin dance also exists as a social dance to help build human relationship. Therefore, a growing attention is being put to the research and teaching of Latin dance.

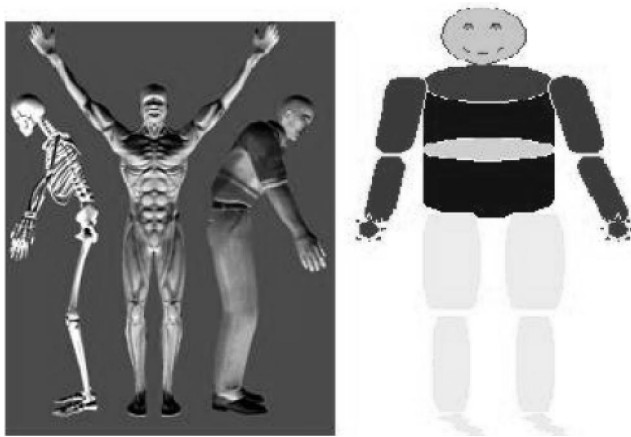
Main categories of Latin dance research at present are: Teaching and training (23.7), sport dance and college course (17.04%), effect and value (10.37%), subject research (8.89%) and others (7.41%). All of types above consist of 67.41% of all papers published on this topic. Wu Dongfang, Qian Jingguang, Li Jianshe and other researchers have profound studies on Latin

dance. However, we should see that most of these researches are purely based on experience, which accords with aesthetics and art forms. There are very few studies that are based on natural science theories. This paper studies the barycenter leading problem based on biomechanics theories and precedent studies. This paper presents an analysis of existing barycenter leading movements with biomechanics theories to verify correctness according to experiences and art as well as gives an outlook of the developing trend of Latin dance.

**HUMAN BODY BARYCENTER MOVEMENT MODEL**

**Multiple rigid-bodies model and their barycenter positions**

Human body consists of head, torso, upper arm, forearm, hand, thigh, calf and foot, as shown in Figure 1.



**Figure 1 : A dancer’s rigid-bodies model**

A rigid-body model separates the human body into head, arm, leg and foot etc. When a dancer’s posture is set, all barycenter of parts of his body are set too. The positions of all barycenters are related to the mass distribution of all parts of body. The equation for coordinate for all barycenters of parts of human body is:

$$\begin{cases} M_j = \lim_{n \rightarrow \infty} \sum_{i=1}^n m_i \rightarrow x_i = \frac{\sum m_i x'_i}{M_j}, y_i = \frac{\sum m_i y'_i}{M_j} \\ M = \sum_{j=1}^n M_j \end{cases} \quad (1)$$

In equation (1),  $M$  is the total mass of human body,  $M_j$  is the total mass of all parts of body,  $x'_i, y'_i$

are the horizontal and vertical coordinates of every infinitesimal mass point,  $x_i, y_i$  are the horizontal and vertical coordinates of barycenter of all body parts.

The point of action of the resultant force of all parts’ gravity forces is called the human body barycenter. According to the rigid-body model in (1), we can separate the human body into parts. When the dancer moves to a new posture, a new barycenter position can be found by resultant moment theory, as shown in equation (2):

$$\begin{aligned} PX &= \sum p_i x_i, \because P = 1, \therefore X = \sum p_i x_i \\ PY &= \sum p_i y_i, \because P = 1, \therefore Y = \sum p_i y_i \end{aligned} \quad (2)$$

In equation (2):  $X, Y$  are the horizontal and vertical coordinates of the barycenter of the dancer.  $p_i$  represents the weight of every part, and  $x_i, y_i$  are the coordinates of barycenter of all parts.

Since we are studying the force when we discuss the movement of the barycenter, we name the line that goes downward from the barycenter the barycenter line.

**The law of barycenter line movement between dance partners and analysis of its stability**

Partners realize the leading by making their barycenter line overlapped. To overlap their barycenter line, is to make the barycenters of two dancers closer enough to be integrated by two’s arms, and to function as resultant force in movement.

The surface that all supporting points encircle is called supporting surface. In Latin dance, the supporting surface is the area among the four feet of two dancers. When the barycenter line is out of the area, it will result in the offset of the bodies, so dancers ought to keep the barycenter line in an appropriate area. Now we discuss the stability of the bodies with the emphasis on the relationship between barycenter line and supporting surface.

The body balance status can be categorized by the level of stability:

**Stable balance**

When the body drifts away from balanced position, the barycenter rises and the gravity force make the object move back to the balanced position, thus the resultant force and moment are zero.

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### Unstable balance

When the body drifts away from balanced position, the barycenter lowers, the gravity force moment makes the object continue to lean. This only happens when in the balance movement with underneath support.

### Limited stable balance

When the body drifts away from the balanced position to a limited extent, the barycenter of human body rises, and the moment of gravity drives the body till it reaches balanced position. But if the body drifts too far from the balanced position, the barycenter of human body will fall and result in further offset of the body from the balanced position.

### Free balance

When the body drifts away from its original position, the barycenter doesn't move vertically so no gravity momentum is there to make the object move.

In all, the stable status of human body is virtually a varied form of balance, i.e. dynamic balance or static balance. One factor that influences the stability is the stability angle, the angle between the barycenter line and the extended line from the edge of supporting surface.

The stability coefficient  $K$  shows the level of stability of the object, which is the quotient of stability moment divided by toppling moment. The Figure 2 shows the discussion of stability coefficient.

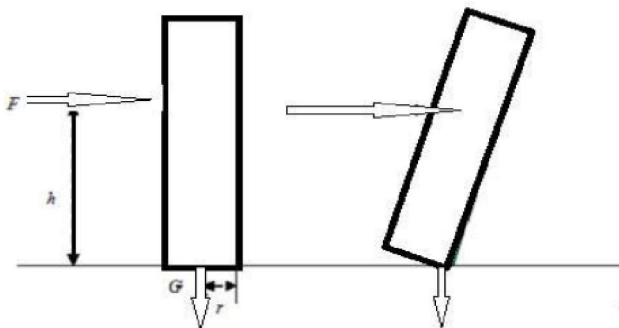


Figure 2 : Stability moment and toppling moment

The equation of stability coefficient:

$$K = \frac{G * r}{F * h} \quad (3)$$

So when  $K \geq 1$ , the object is stable, otherwise the object would topple.

## ANALYSIS OF LEADING METHODS

The connection and leading of two dancers in Latin dance is not as fixed or tight as in standard dances. However it also requires the dancer to utilize the position relationship with his partner to control the connection and leading.

Latin dance is a two partners dance. In one set of dance steps, the steps of the man and woman are not symmetric. That is to say, the man and woman have their own movements to do. The man is responsible for leading, aiding the woman and also controls her body barycenter to help her complete her movements. While the woman is always waiting for the man to lead her to complete every pre-designated movements in the dance periods designed by the man.

The following is an analysis to three kinds of leadings categorized by the way barycenters are connected and power used in connection.

### Permission leading

Permission leading is a combination of the movements of the shoulder, elbow and wrist. The arm moves forward gently with almost no power. In Latin dance the forward steps and backward steps are not opposite in sequence, therefore when the man is in a closed position or relative open position and is doing a forward step, the woman needs to give a permission for leading. The leading, for man, means doing forward steps while for woman it means to answer to man's signal with an arm motion as well as to do backward steps with the help of man's movement.

In posture "1-3 Basic Steps" in separated positions, mans and woman's movements of barycenter don't happen at the same time. In eats 1&2, as it shows in Figure 3 in the left, man's body moves forward first while lower his arm that holds the woman. At this time, man's moving his barycenter forward will make the woman go backward, followed by man's movement of his left foot thus to shift the barycenter to the position between his feet.

As it is shown in Figure 3, when man's arm (body->shoulder->elbow->wrist) shows tendency to move forward, the woman should extend her right leg backward and tiptoe the ground. Then the woman should

lower her right heel slowly, making the barycenter line at the force point of her sole. When the man completes moving the barycenter to his left foot, the woman moves her body's completely to the right root, following the permission leading by the man.



**Figure 3 : 1-3 Basic Steps in a relative separated position**

### Limb leading

Limb leading is that dancers connect their body barycenters by arms and lead his partner into pre-designated position by means of push or pull in a gentle manner.

Compared to permission leading, the limb leading has a clearer way of using the power and a better control. To make sure that the woman can complete her motions with perfect balance and fluency, the man should manage her movement of barycenter line according to the right beat of music with limb leading from the beginning to the end. A correct limb leading will boasts their level of mutual understanding. For advanced dancers, limb leading provides the "light & shadow" and "points & lines", thus help them to create the harmony of their dance.



**Figure 4 : Centered leading in changed line dance postures of cucaracha**

In Figure 4, limb leading are displayed in changed line dance postures. In the left of the Figure, arms of two dancers are bent at beat 1 & while their center lines of the body are close. After the change hands, a push is realized. In the middle Figure, the right hand of the man and woman are moving away from each other so as to make the barycenter line to do the same. In the right

Figure, the barycenter line of the man is leaning left on beat 3 4.1 while the woman's is leaning to the opposite direction. The motion of the arm changes to pulling from pushing, and the right arm of the man controls the barycenter movement of the woman.

It is complicated to control the changing line dance postures in Cucaracha. Therefore it is crucial to connect the barycenters and manage the leading technique to make the dancing movements in shape and accord to the beats.

When the leading motions of the man don't coordinates with the beats or periods of steps, the woman will feel uncomfortable at performance. So the man should lead the woman with the correctness of time and space with a good manage of force, thus to make their barycenters closely connected and to provide good effect for motions.

### Hint lading

In two partners dance of Latin dance, that the man leads the woman with no power, that is to say, with no connection between barycenters is called hint leading. It is realized by hint the woman to go into the pre-designated position to complete motions or turn to some direction by giving poses of the body or arm as well as way of shaking hands or eye contact. In all dancer steps connected by arms, man will use power that nearly unable to be felt to hold woman's arm to do the hint leading. At this time, there is no need for the woman to give the man an answer.

The man hints the woman to get closer by eye or body movements. At the same time, he design space for the woman by waving his right arm and turning his body, thus to tell the woman the position she should go to. The control in hint leading is more complicated than that of permission leading and limb leading. It requires a very high level of body language communication for both dancers, as well as fine awareness of dance expression and understanding. An effective hint leading can only be realized when all premises and conditions are fulfilled.

By the analysis of hint leading techniques, it is easy to know that hint leading is realized by training, as it requires the dancer to understand the partner's eye or body hints after she managed all basic skills.

## ANALYSIS OF THEORY OF LEADING TECHNIQUE

The three leading techniques are divided then ana-

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lyzed here, and in process of dance there will never be only one of them, instead, they will come in combinations. In all, they realize leading by leading the barycenter of the bodies. In an effective process of leading, the arm should be kept in an appropriate connection with the body. When the lead leads his partner with his arm, he should first connects himself to the barycenter of his partner before he connects his arm's barycenter to his partner's, thus to make partner's barycenter move.

Leading with the body barycenter is more complicated than using techniques and skills, both mechanically and technically. However, we can prove the correctness of the technique with mechanics theories and to provide model for later computer simulations.

In motions of dance, the arm moves faster than the barycenter of the body. If the arm is used to lead, it will pose a force onto the partner and make her unbalanced and damage the dance motions. If the lead leads with body barycenter, both dancers will dance harmoniously.

Learners of Latin dance will probably first ignore the importance of moving barycenter at a constant speed and lead with larger movements of steps and arms, which results in the loss of balance of himself and his partner. When he gets some experience on that, he can manage to lead by the barycenter of the body and his steps will follow naturally. At this time, he will find that the size of steps plays a little role in leading while the real factor is the movement of barycenter of the body.

The leading motion is a conduction of the momentum. It is done by the lead's passing his body momentum to the follow. The way of conduction is shown in Figure 5.

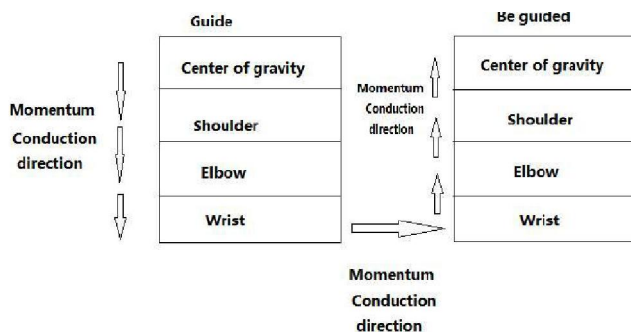


Figure 5 : Barycenter momentum conduction

As a conclusion, when the lead guides the partner with his body, he can motivate the body once the barycenters are connected.

## CONCLUSIONS

In two partners dance of Latin dance, the cooperation of the dancer and his partner is not only guaranteed by mutual understand, but also by scientific theories. Former studies are mostly based on experiences, so the study can be much more effective when conducted with the help of natural science.

In the movement of Latin dancers, the stability is related to the stability coefficient and the surface area is related to the stability angle. The dancer can adjust the dancing postures to change these factors thus to make the dancer better.

In permission leading, the arm should move gently; in limb leading, the arm moves clearly; in hint leading, no real connection exists. However, in a real dance, leading realized by movement of barycenter always appear in all forms in combination. It serves an important role in keeping the tempo fluent and the shape of dancers harmonious.

The paper shows that leading by only arm or big step will result in the loss of balance of the lead himself and the partner, thus affect the dance.

This paper gives a detailed analysis of how dance can be coordinated with beats in two partners dance. It draws the conclusion that the woman should follow the lead of the man while the man should have a good control on the woman's barycenter, both in terms of control level and method.

This paper studies the theory regarding of the barycenter movement in Latin dance. It shows the technique in detail and analyzes some inappropriate movements as well as some points easily ignored.

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