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BIOMECHANICAL ANALYSIS AND METRIC INTERPRETATION OF 'WALKING' IN TANGO DANCE

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Abstract

During the 20th century, tango dancers affirmed that their choreographic figures were an extension of the "spontaneous street walk" further adding that it was important to "walk with cadence" and know how to "keep the beat of the music". In this paper we try to address the *material* meaning of these valuable popular assertions that, to this date, have not merited sufficient substantiated research. We comparatively analyze the cycle of human walking and tango walking from a biomechanical and kinesthetic perspective. Preliminary results show that (i) the tango step has a particular internal rhythm and micro timing that can be characterized by the periodic alternation of a series of dichotomous categories; (ii) there is a biomechanical foundation for a strong-weak hierarchy in the structure of the gait and its relation to the isochronous marking of its music. These findings have implications in the teaching and learning of tango, in that they contribute to improve the way in which we observe, analyze and metrically situate details of the tango walk. Finally, evidence is presented that reveals that walking structure was an antecedent of the isochronous marking of tango music.

Resumo

Durante o século XX, os bailarinos de tango afirmaram que as suas figuras coreográficas eram uma extensão do 'caminhar espontâneo da rua', acrescentando que era necessário 'caminhar com cadência' e saber manter o compasso' da música'. Neste artigo tentaremos abordar o significado 'material' dessas valiosas afirmações populares que à data não têm merceido suficiente investigação fundamentada. Analisamos comparativamente o ciclo da marcha humana e do caminhar do tango desde uma perspectiva biomecânica e cinestésica. Mostramos que (i) o passo do tango tem um ritmo interno particular e um *micro timing* que pode ser caracterizado pela alternância periódica de uma série de categorias dicotômicas; (ii) há um fundamento biomecânico para uma hierarquia forte-fraca na estrutura do passo e sua relação com a marcação isócrona da sua música. Estas descobertas têm implicações no ensino e na aprendizagem do tango, na medida em que contribuem para melhorar a forma como o fazemos, analisamos e situamos metricamente detalhes do 'caminhar' do tango. Finalmente, são apresentadas evidências que revelam que a estrutura deste caminhar foi um antecedente da marcação isócrona da música tango.

Palavras-chave: *Tango dança; Metro musical; Gait cycle; Análisis Biomecânico y Cinestésico.*
Key-words: *Tango dance; Musical meter; Gait cycle; Biomechanic analysis; Kinesthesia*
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BRIEF ONTOLOGY OF TANGO

From the ontological perspective proposed by historian José Gobello (1980), tango dance "is nothing but the Africanization of the mazurca and the milonga; Tango in its origin is not a dance, but a different way of dancing what was already being danced". On the other hand, Gobello adds that the "African characteristics (…), in this manner of dancing, were *el corte y la quebrada*[2] (p.18). Around 1870, *criollo*[3] *compadrito*[4] appropriated these African gestures, adding to them the couple dances embraced, settling on the Habanera pattern (composed of 4 beats which in written representation consists of a dotted crochet-quaver-crochet-crochet). One of the first recordings of the tango *Emancipación* by Juan Maglio 'Pacho' from 1912 demonstrates the rhythmic accompaniment based on the habanera. https://www.youtube.com/watch?v=Wj0-vjScBMY.

According to 'Viejo Tanguero' (Diario Crítica of September 22, 1913), tango dance, in its origin, was of "soft undulation, rhythmic and daring". It is also stated that "it has its own meter and time signature within which performers must adjust to the special swing set by the music. Flexion is one of the most determining details. If the dancer fails to imprint this cadence within its true timing, the piece lacks interest " (p.4).

The Habanera accompaniment was exclusive to all of the so-called tangos of Río de la Plata until the end of the period designated as *Guardia Vieja* which finished at the end of the 1920's.

However, since the end of the first decade of the 20th century, tango underwent great innovations, changing not only its figures, but also its elasticity and flair, which was originally its main characteristic. Interpreted by women, mostly Italian, "they did not adapt themselves to the movement imprinted in it by the native criollo and thus it was given the name of *tango liso*[5] [emphasis added] (…) losing its primitive air" (p.4).

[2] *Quebrada* (break) is the wiggling of the hips and *corte* (cut) is a pause or interruption in the dancing "walk" (Petit de Murat 1968)
[3] people born in Río de la Plata, of Spanish descent.
[4] C*ompadrito* (or handsome) is a young man of modest social status who lived on the shores (suburbs) of the city of Buenos Aires, Rosario and Montevideo in the second half of the 19th century. Cutler, provocative, boastful and quarrelsome. One of the protagonists in the creation of Tango.
[5] smooth tango.

In 1920, *Orquesta Select* introduced a new marking pattern - known as *marcato en cuatro*[6] - played at a slower tempo and built upon an isochronous rhythm in which the first beat of a series of four feels accentuated. This new rhythmic marking can be seen in the tango *El Marne* performed by the *Orquesta Select* in 1920. https://www.youtube.com/watch?v=a9Hobu1KGwk.

Years later, in 1935, Juan D'Arienzo's tangos adopted a very energetic marking, staccato and at a faster tempo. A very dance-oriented way of playing that earned him the nickname 'The King of of the Beat' and other descriptions such as D'Arienzo "would return the tango to the dancers' feet." (Retrieved from http://www.todotango.com/creadores/biografia/32/Juan-DArienzo/).

An example for this is the tango *Tinta Verde* from 1935 performed by his typical orchestra https://www.youtube.com/watch?v=G0w5Vs2B0fw.

In the 1940s, dance finds its golden era. During this period, popular narratives about the essence of dance speak in terms of knowing how to walk with the beat, cadence and elegance, stepping on the times, dancing the silences and doing all of this with the same ease with which we walk in the Street. There is a use of musical terminology that alludes to a dance gesture clearly defined by the action of walking.

Taking as a starting point previous works (Grosso Laguna, 2019, 2018; Laguna, 2018; Laguna Grosso & Shifres, 2018) the present study investigates how the mechanism of human gait could be transformed into an aesthetic, expressive and rhythmic elaboration of dance and tango music.

BACKGROUND

Dance: Walking and the embodied perception of the beat

The bipedal locomotion process is probably the most widely used and developed movement pattern in dance. All dance styles use the step pattern one way or another.

[6] *Marking in four*. This denomination is currently widely used by the Argentine musician Ignacio Varchausky in his work *The Fundamental Styles of Tango*. Additionally we point out that the emphasis placed on the isochronous rhythm of the first notes of the tango *La Cumparsita* (1915-16) by Gerardo Matos Rodriguez is a precedent for marcato en cuatro.

These notions were already familiar to dancer and choreographer Doris Humphrey (1959) who considered that the most important source of rhythmic organization for the dancer was motor rhythm (compared to that of breathing, heartbeat, and emotional rhythm) describing it as "the propelling mechanism, the legs, which man discovered would support him, one after the other, while moving in space, and which provided also a conscious joy in beat as the weight changed" (Humphrey, 1959, p.105). Furthermore, "this is where the origin of dance begins - with the feet - and this is where it is mainly maintained", emphasizing that the "awareness of the accent [and] the pronounced energy of the beat comes only from the weight shifting in dance" holding that such consciousness "would not exist in music, language and the visual arts if it had not been established by man's foot" (Humphrey, 1959, p.105). In addition, Humphrey (1959) describes in a very interesting way the mechanism of walking which

> consists of a balance on one leg while the other is lifted and advanced by the muscles. As the descent of this leg begins, force is no longer necessary. Gravity takes over, and the foot strikes the surface with only a braking action, which results in the familiar "footfall". The down stroke can be emphasized and reinforced by energy (…) Nevertheless, it is gravity which provides the beat potential (Humphrey, 1959, p.106)

Humphrey concludes by stating that the key pattern of the walking mechanism is a fall and recovery, the give and take rebound from gravity, a gesture that manifests itself primarily in walking and is the very core of all movement. In dance this process is highly specialized and amplified, from it emerging all qualities of accents. The Portuguese dancer and rehersal director Vítor García makes an interesting observation about walking in dance: "dance is a sophisticated way of walking" (June 2011, in private conversation).

Biomechanical structure of the gait cycle

> Locomotion is probably the most common everyday activity of higher animals, including humans. It is defined as a motor action during which the location of the whole body in the environment changes. There are many types of locomotion such as crawling, flying, swimming, hopping, walking, and running (…) I consider mostly walking and running as the two most common modes of locomotion used by humans (Latash, 1998, p.172).

One of its fundamental principles is the *automatic and* balanced control of postural activity during body movement. Jacquelin Perry (1992), a pioneer in the biomechanical research of gait, states that walking forward on ground level is the basic pattern of bipedal locomotion which consists of a:

> repetitious sequence of limb motion to move the body forward while simultaneously maintaining stance stability (…) as the body moves forward, one limb serves as a mobile source of support while the other limb advances itself to a new support site. Then the limbs reverse their roles (…) A single sequence of these functions by one limb is called a gait cycle (p3).

During gait the leg movement flows smoothly in order that any event could be considered as a specific starting or ending point. Several authors (Perry, 1992; Murray, Drought, & Kory, 1964) have considered that the easiest event to observe is the *initial contact* of the foot with the ground (onset) and therefore adopted this location as the beginning of the gait cycle. Accordingly, the successive contralateral initial contact defines the *step* and the following ipsilateral contact defines the *gait cycle* (or stride).

Repetition of this sequence of lower movements involves a series of interactions between two multisegmented limbs (toes, heel, knee, hip) and total body mass, therefore the identification of the numerous events that occur within each cycle requires the step to be observed from different approaches such as variations of reciprocal support of the contralateral feet, the qualities of the step with respect to time and distance, functional meaning of the events that occur in the gait cycle and the intervals that occur between them (Perry, 1992). The same researcher describes that when walking "a change in direction increases the requirements. Stairs and rough terrain further the demand. Running and the various sports present even greater needs. Despite these variations in complexity, there are underlying functional patterns common to all" (Perry, 1992, p.19).

This statement is particularly relevant to our study for it allows us to extend biomechanical analysis of gait towards the study of the tango *walking* pattern.

The gait cycle (see Figure 1A) is divided into two periods that describe the total activity of one leg between two ipsilateral contacts: the stance period and the swing period.

The stance period designates the time during which one foot or both feet are in contact with the ground. It begins with the initial contact of the heel and ends when the big toe of the ipsilateral foot lifts off the ground.

The swing period refers to the period during which the foot is in the air and moving forward (or going back in case the action is performed backwards). It begins when the big toe is lifted off the ground (toe-off) and ends when the ipsilateral heel makes contact with the ground. According to the Rancho Los Amigos the categorization, the gait cycle

(GC) is divided into 8 functional phases, (1) initial contact, (2) loading response, (3) mid stance, (4) terminal stance, (5) pre swing, (6) initial swing, (7) mid swing, (8) terminal swing (see Figure 1A).

Figure 1A. Phases of the GC between two ipsilateral contacts of the right leg.

Source: Image from the author.

Gait Cycle Description

The gait cycle begins when the heel (right in this case) rests (heel strike) on the ground (0-2% GC) and the body enters a bilateral support situation called initial double stance (see Figure 1A). At this moment the loading response phase (2), (0-10% GC) occurs. When the foot of the contralateral leg loses contact with the ground (toe off) the body enters the first half of the single limb support (2-3), (10-30% GC) extending itself

until the body weight is aligned vertically on the forefoot and finds its state of greatest balance (3). During the second half of the single limb support the body moves out of its base of support and when the heel loses contact (heel off) with the ground the body is in its terminal stance (4), (30-50% GC) which ends when the opposite leg rests on the ground and the body is in its second double stance situation (terminal). This moment in which the right leg prepares itself to move forward is called the pre-swing phase (5), (60-73% GC). When toe-off (6) occurs, (60-73% GC) the initial swing phase begins. The knee is raised and advances until the swinging limb is opposite the stance limb (7), (73-87% GC). The mid swing phase ends when the tibia is vertical. The terminal swing phase is the last phase of the right leg's GC, beginning at the vertical tibia (8), (87-100% GC) and finishing once the foot concludes its advance when making contact with the ground.

In the sequential combination of the limb movement, three basic tasks are distinguished: weight acceptance (1-2), single limb support (2-4) and limb advancement (5-8) (see Figure 1A). Weight acceptance occupies the first two phases of the gait cycle: initial contact and loading response. It is the most demanding task in the gait cycle and involves three functional patterns: shock absorption, initial limb stability, and the preservation of progression. It extends from the initial contact (heel strike) until the 5 distal phalanges of the contralateral foot lose contact (toe off) with the ground. The main challenge of weight acceptance is the abrupt transfer of body weight onto a limb that, as it finishes swinging forward, has an unstable alignment (1-2).

Single leg weight bearing (2-4) continues until initial opposite leg contact occurs. During this interval the supporting limb has the responsibility of supporting the body weight in the sagittal and coronal planes while body progression develops during the mid stance phase and terminal stance phase.

Advancement of the contralateral limb (5-8) starts being prepared at the terminal double limb support (pre-swing phase) and takes place during the single limb support period. During the swing period the limb rises, moves forward and prepares for a new rest during the initial phases of initial swing, mid swing and terminal swing.

Analysis of bipedal locomotion divides the body into two units, the *passenger* and the *locomotor system*. The first is made up of the head, neck, trunk, pelvis, and arms (70% of the body's weight). The second unit is made up of the lower extremities as well as the pelvis, which plays a double role by establishing, on the one hand, a mobile connection with the lower extremities, and on the other, being the lower segment of the *passenger*

who ‘rides’ on the coxofemoral joints of the hip. The functions of the locomotor system are propulsion, stance stability, shock absorption, energy conservation. Each function depends on different movement patterns representing complex series of interactions between the body mass and the multi-segmented movement of the lower limbs.

In terms of durations in a gait cycle, 40% of the time is dedicated to the middle stance phase and swing period while 10% of the time is devoted to each double stance interval (initial and terminal). These percentages vary according to the speed rate of the walk. When the step speed is increased, the resting period and swing period reverse their durations until the double support phase is lost when running (Bramble & Lieberman, 2004).

The tango music of the Guardia Nueva

As we have seen, since 1920 the rhythmic uniformity of the habanera accompaniment gives rise to a new rhythmic pattern called marcato en cuatro. The experience of tango music is organized in a 4-beat *metric structure* (Lerdahl & Jackendoff, 1983; Fitch, 2013; Shifres & Burcet, 2013; London, 2012) of binary subdivision. In this structure - mental and made up of pulse levels of different tempi - the sounds that correspond to the base pulse of beats one and three occupy strong metric positions and those that correspond to beats two and four to weak metric positions. In terms of written representation tango is written in a 4/4 time signature. One of the most prominent characteristics of the style is its performance of rhythmic, dynamic, articulatory, timbral contrasts and the expressive use of rubato. The regular flow established by marcato en cuatro is usually 'interrupted' by beat and bar syncopations, orchestra contrasts between tutti-solo as well as legato sections that alternate with stacatto sections.

There are several types of marcato en cuatro: the 4 beats are accentuated with the same intensity (phenomenal accents), the first beat is accentuated, or the first and third beats are accentuated, or the second and fourth. In this last example the weak metric positions are accentuated producing a displacement of the accent with respect to the strong metric position.

In terms of rhythmic contrasts, we suggest listening to the tango *La Bicoca* performed by the Juan D’Arienzo orchestra in 1940.
https://www.youtube.com/watch?v=35l1dfBkTVw

Other essential aspects of this evolution, such as instrumental development from sextet to orchestra, the singers and the arrangements, are not here referred as they exceed by far the scope of this work.

OBJECTIVES

This work aims at demonstrating that there is a biomechanical and kinesthetic foundation that indicates a metric hierarchy - strong-weak relationship - in tango walk.

Provide evidence that the hierarchical periodicity of walking could have led the tango accompaniment towards the marcato en cuatro.

MAIN CONTRIBUTION

Part A - Embodied approach

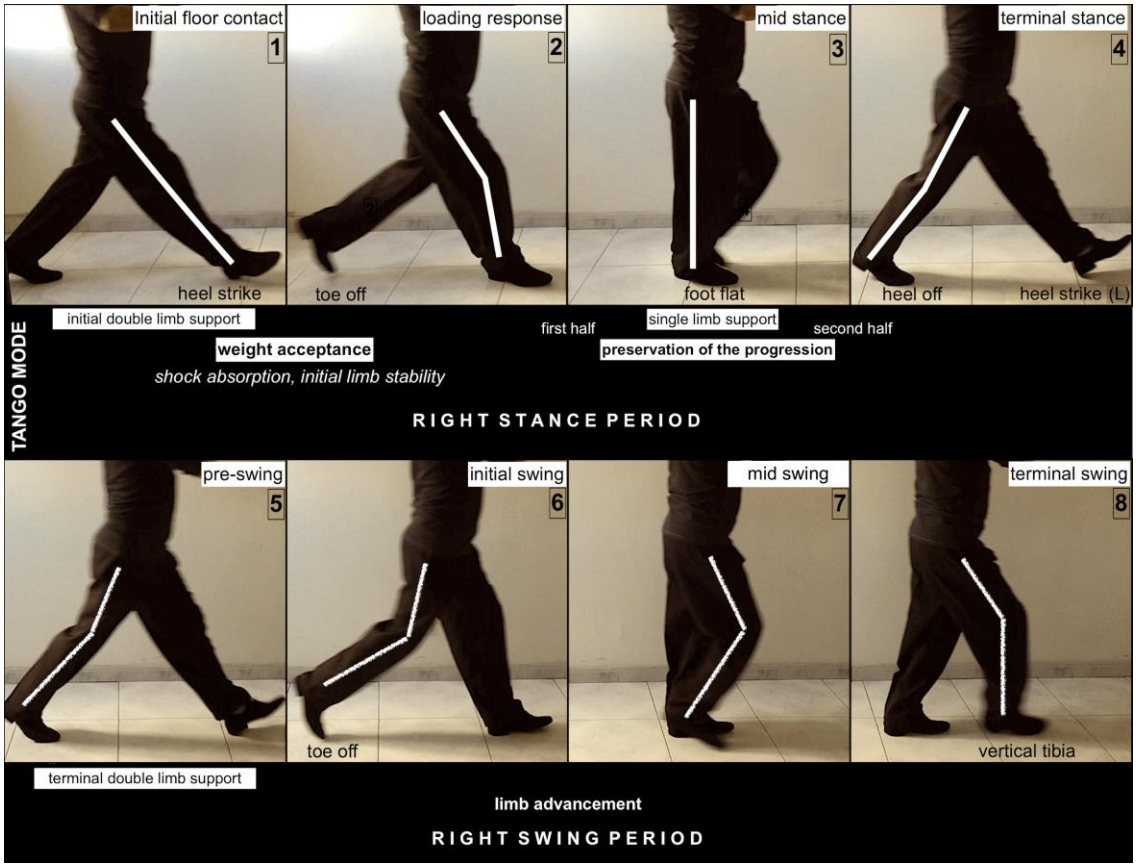
Street walking vs tango step

Four professional tango dancers (two female and two male) performed self-observation tasks in order to test the functionalities of the biomechanical analysis here presented (periods, phases, tasks) in their own movements. Three meetings were held, spread over two weeks. Participants were encouraged to perform their steps in different directions (forward, backward, sideward, changes of direction) and dynamics (attack, fluidity, speed) individually as well as coupled, with tango music and without music, and to transform street walking into tango walking (and vice versa). At the end of each meeting, they were asked to describe their experiences in *kinesthetic* terms (Sheets-Johnstone, 2010, 2011). The empirical observations of the participants presented strong coincidences:

- The GC phases can be identified in tango mode both in forward and backward movement. Regarding the backward step, participants noticed that foot supports are reversed (phalanges-metatarsal-plantar-heel).

- In street mode "we put the weight offload in the heels and hips, as if the trunk were behind or above the heel". "Knee flexion and the extension from leg to foot reaches its limit automatically. We are not aware of the use of our body center". On the other hand, when tango walking "we control those limits, the body is more aligned", "we control all parts of the body, the knee, how and when I stretch, where my center is".
- Walking as a couple is presented as "a new system of locomotion". It is much more than "two bodies and four legs" that move in the opposite direction. "My body includes the other, we have to learn to walk together".
- By transforming the street step into a tango step, a significant reduction of steps per minute (SPM) is produced. According to the measurement done by participants when tango walking, they performed between 60-72 SPM, a notably lower value (75%) than the one we adopt when walking down the street which varies between 105-120 SPM (Perry, 1992).
- They observed that in street mode the body moves at a constant speed, uniformly and without impulses. "The rhythm of the step feels as if it were always in each resting point". "The middle of the step [middle phase] is unnoticed as a sensation because" one simply goes through it. On the other hand, when tango walking "one feels this middle phase as a retention, a preparation, an intention of tango". Body speed is not uniform, because in each step we feel it moving "faster and slower as we get closer to or away from the axis" [mid stance].
- The participants explained that (when tango walking) they intentionally reconfigure the muscular arrangement of the body through stretching, oppositions and spirals.
- In tango mode the extension of the individual step is approximately 20% greater than in street mode (measurements between initial contacts made by participants). Figure 1B shows the 8 phases of the GC in tango walking, where the difference in step extension, with respect to walking in street mode, can be seen. (Compare with Figure 1A).

Figure 1B. Phases of the GC in 'tango mode' between two ipsilateral contacts of the right leg. The eight phases and three basic tasks are identical to street mode.



Source: Image from the author.

In summary, the participants mainly agreed that street walking consists of a series of automatisms that are lost when we start walking in tango mode. And when lost, we become aware that we need to control a series of variables — such as weight shifting, balance, direction — that were masked in those automatisms. The tempo variable acquires a qualitative, expressive and intentional dimension. In addition, our movements become synchronized to an external musical stimulus with a tempo rate significantly lower than that of street mode and all this we have to organize 'between two' walking embraced, and in doing so we have to add a new direction we are not used to. Walking backwards.

Part B - Biomechanical approach

Rhythm, periodic alternation and symmetry in gait

During the gait cycle, a series of rhythmic patterns of movement are produced by the hip, knee, and ankle, which are a consequence of the selective advancement of the limb segments and of the various changes in alignment between the trunk, the hip and the kickstand. Large arcs of motion occur in the sagittal plane although there are subtle actions that occur in the coronal and transverse planes. These adjustments generate

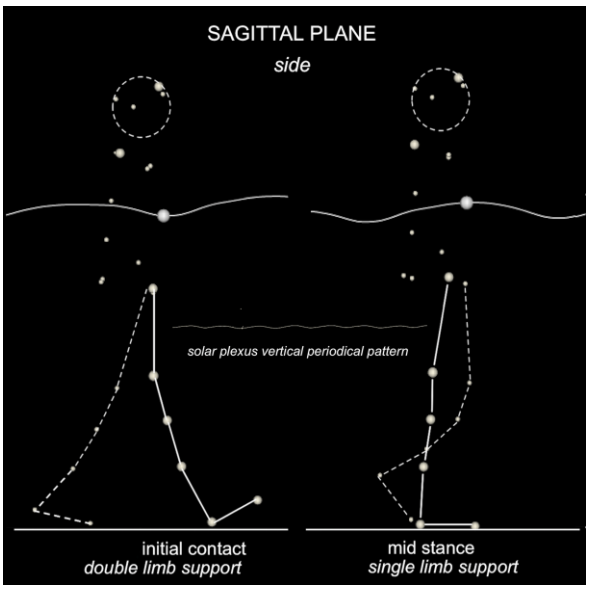
patterns of variation in height, lateralization, contralateral rise-and-fall of the hip and rotation of the pelvic girdle with respect to the shoulder girdle. These are slight adjustments which produce shifts in the gravity center (located around the solar plexus) in the line of gait progression (Perry, 1992).

How are these body adjustments related to the GC phases? How are these rhythms felt as part of the step?

In a laboratory environment, we analyzed these questions by recording, through 18 position sensors, the walk in both street mode and tango mode (with music) of a dancer (one of the participants) using the VICON Motion Capture system. From the set of 18 sensors, we take as a reference only those that, due to their location, are essential to define the phases and adjustment patterns. These are the heel to identify the initial contact (heel stroke), the big toe of both extremities to identify entry in the middle phase (toe off) and the upper center of the head for longitudinal alignment with the forefoot (division of the step in two). The body adjustments referred by Perry (1992) were observed by the marker trajectory length left by the solar plexus and the superior iliac crests.

The participants were confronted with the 3D recording of the dancer's movement in different planes and were asked to describe what they felt. We further describe the adjustment patterns in street mode. Vertical rhythm. Figure 2 shows that the body (and the GC) reaches its greatest height in the mid stance phase (longitudinal alignment of the body on the forefoot) and its lowest value in the initial contact phase.

Figure 2. (Street mode). Vertical rhythm in the sagittal plane.

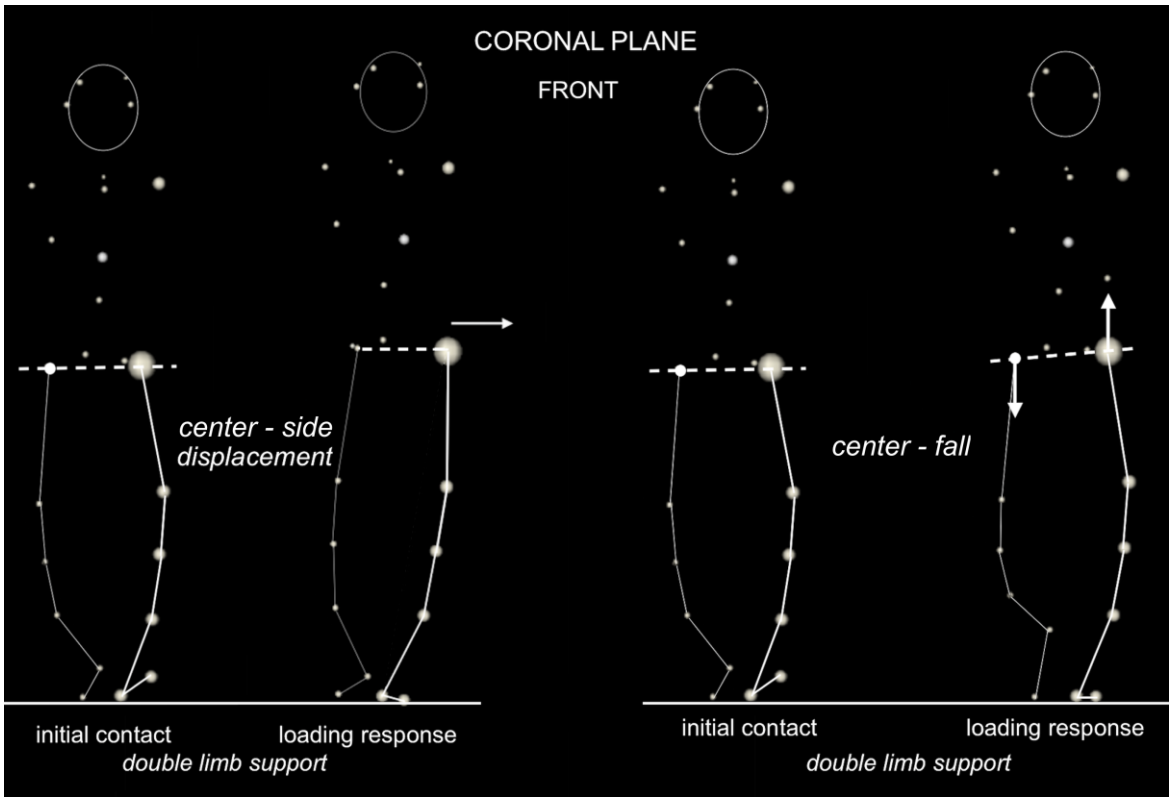


Source: Image from the author.

Lateral rhythm of the pelvis (see Figure 3 Left). During the loading response phase, the pelvis deviates laterally in the direction of single limb support.

Rhythm of elevation and contralateral fall of the hip (see Figure 3 Right). As the body advances, during the interval of initial contact-loading response phase the iliac crest sensor corresponding to the pelvic side of the supporting limb rises while the opposite side (iliac crest sensor) descends. During mid stance the pelvis is leveled and the process is repeated from the next initial contact.

Figure 3. (Street mode). Left panel. Rhythm of lateral displacement in the middle phase of the pelvic lateral rhythm support period. Right panel. Rhythm of Contralateral rise-and-fall of the hip in loading response.



Source: Image from the author.

Rhythm in the transverse plane. It consists in the rotation of the pelvis in the direction of the swinging limb displacement. The rotation starts from the mid swing phase and ends when the limb completes its swing and rests (pre swing phase).

Analytical observation of the four rhythms produced in each step cycle shows that these are periodically articulated between the phases of initial contact and mid-stance. Each step is made up of two levels of periodic regularity. The first establishes a cycle every two consecutive initial contacts (step) and the second divides the step cycle into

two equal halves (end of the first half of the mid stance phase). The superposition of levels (see Figure 4) produces a metric hierarchy of periodicities that establishes a superordinate relationship - subordinate between the phases of initial contact and mid stance. Accordingly, by nature we will feel the heel strike as the most accentuated instance of the step and the mid stance ('half' of the step) as the least accentuated instance.

Regarding the experience of having observed the walk from the sensors' perspective, the participants explained that they were not aware that when they walked these adjustments took place and, even less, that they had such a rhythmically defined evolution. They reported, on the other hand, that the 'technological' observation of movement allowed them to identify and explore those patterns in their bodies. One of the participants pointed out that "when they teach us how to dance tango they tell us that we cannot go up and down, or that the hips do not move sideways" however, our body does this naturally and this shows us that there are beliefs that are not consistent with the measurement". Finally, they pointed out that the observation of the walk through sensors and at different levels, puts in evidence that our body movement results from a *symmetric*, *equidistant* and *periodic organization*.

The biomechanical analysis and empirical accounts thus far presented, indicate that the rhythmic nature of walking shares characteristics with the *metric structure* of tonal music, understood as the regular, hierarchical scheme of beats that the listener relates with the music he perceives (Lerdahl & Jackendoff, 1983) .

We will now present that during the walk, periodic alternations of another nature reinforce the hierarchical structure of the gait (strong weak) that we have described. According to Bramble and Lieberman (2004) the action of walking behaves like

> an 'inverted pendulum' in which the center of mass vaults over a relatively extended leg during the stance phase, efficiently exchanging potential (Ep) and kinetic energy (Ek) out -of-phase with every step (...) between heel strike (HS) and MS [mid stance], the exchange is reversed between MS and TO (Bramble & Lieberman, 2004, pp.345-346).

In other words, there is an alternation between maximum E_k the instant the foot touches the ground (and therefore the GC acquires greater speed) and maximum E_p when the body aligns itself on the forefoot (where the GC finds its lowest speed).

Already in relation to dancesport, Mora (2013) states that in a sequence of steps in the same direction, the speed of the body center is not uniform, but it oscillates between

higher and lower values, with one oscillation for each walk. This entails that the acceleration oscillates between positive [impulse] and negative values [braking].

Resuming to comparisons made by participants, we were struck by the contrast they established between street mode, the body moves uniformly and at a constant speed, and tango mode, the sensation of going "faster and slower as we move closer to or away from the axis". This suggests that the hierarchy of periodicities is perceived in a more accentuated manner in the tango step. Probably when the alternation of energy (kinetic-potential) occurs at a compatible speed with the temporal range of the *pulse perception* (best resonance arround 500-550ms) (See Van Noorden & Moelants 1999) the dancer can feel and control the alternation of energy of his body in a 'more musical way'. That is, there is a greater resonance of the strong weak relationship in the dancer's body when walking in tango mode (every single step in 60 SPM rate is equally divided in two 500ms periods).

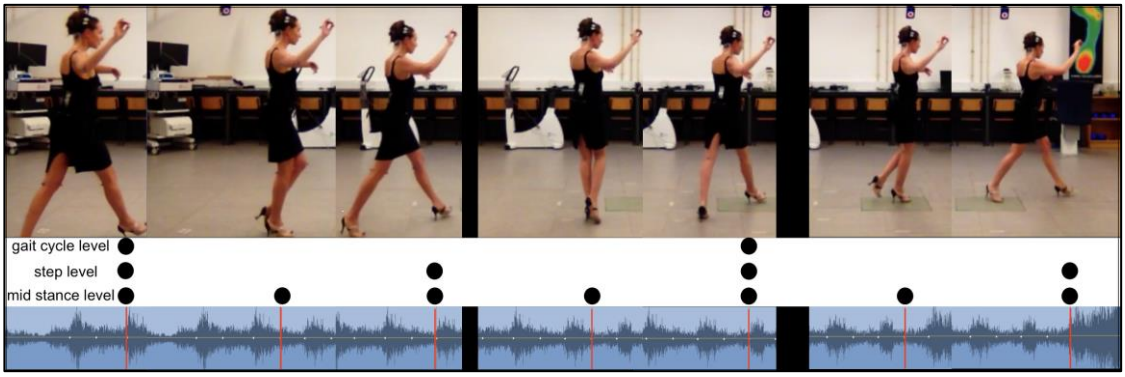
Metric interpretation of the step in tango music

As previously mentioned, Humphrey (1959) refers to the importance of walking to dance and the idea that the body's perception of the beat is associated with the resting foot added to the weight shifter and the force of gravity.

We do not know of objective studies on the relationship between musical meter and tango walk. However, the *milonguera praxis* in its social context (the milonga) indicates that the tango step is 'visually demonstrated' in the music's strong metric position (in its written representation, on beats one and three). As an example we analyze the phases of the tango walk by a professional dancer with respect to the music's strong and weak beat (in Adobe Premiere CS6 software). In figure 4 it can be seen that the dancer makes the initial contact of her foot coincide with the strong metric position and the second half of the single limb support (mid stance) with the weak metric position.

Considering the variations in speed and energy inherent in the gait process, we can affirm that the dancer reaches the strong position of the music with maximum E_k (impulse) and the weak metric part of the music with maximum E_p. The movement thus understood is prepared in the weak metric position. This is the instance of greatest communicative activity of the tango couple and it coincides with what in tango is called 'the mark'.

Figure 4. Music strong-weak metric position correspond to biomechanical initial and mid stance phases. Mid stance level corresponds to tactus level. The superposition of the periodicity levels of the step indicate vertical structures with different hierarchies.



Source: Image from the author.

CONCLUSIONS AND DISCUSSION

This work produced theoretical and kinesthetic evidence that there is a hierarchy of periodicity and a strong weak relationship in the walking structure of tango which is strongly linked to the metric structure and the *marcato en cuatro* of tango music.

Starting from the biomechanical analysis of the gait cycle, we demonstrated that the tango step can be characterized by the periodic alternation of a series of dichotomous categories (Impulse-Braking; Imbalance-Equilibrium; Potential energy-Kinetic energy; Articulatory rhythm up-down / center- side) that are supported by the symmetry and equidistance of the body design. In this alternation we identify the superposition of three levels of regularity. The GC level between two consecutive ipsilateral impacts, the step level between two consecutive contralateral impacts, and the step division level between the initial contact and the end of the first half of the mid stance phase (see Figure 4).

This work addressed the relationship between the instrumental human movement (locomotional, operative) and the human movement as an aesthetic expressive elaboration. We observed that the human gait is organized by a series of *automatisms* that regulate and control the body's balance when moving. There is an automated interrelation between the distance of the step, its speed, the inertia that is generated as a result of the movement of the body weight (impulse and brake) and the body adjustments in each step. In their comparison, the participants pointed out that when walking in tango mode, the automatisms that govern human gait are lost due to the *expressive intentionality* of the

dance. There is an expressive use of time therefore one walks slower, the body becomes more elongated, the weight is moved farther, and the body speed alternates noticeably between a maximum magnitude (initial contact) and minimum magnitude (end part of the first half of the mid stance phase) which implies a greater use of muscular force to expressively model inertia. The complexity of this dynamic is even greater if we consider that we are regulating a step that is done within an embrace, where the other body functions as the extension of our own body, and in which the couple needs to communicate non-verbally in order to coincide their movements with the temporal and dynamic structure of the musical stimulus.

This study gathered preliminar evidence that reinforces the influence of body gestures in the evolution of the rhythmic accompaniment of tango. According to Gobello's (1982) hypothesis, tango began as a different way of dancing to music that already existed. In this sense, we have seen that the *compadrito* (since 1865?) danced, with *corte y quebrada,* European musical styles such as the chotis, mazurka, polka and waltz (see Vega, 2016; Novati, 1980). Around 1880, a new music - tango - built upon the rhythmic of the Habanera became the source and interpretation of the *compadrito*'s dance. Three decades later, due to a series of circumstances such as the success of tango dance in Paris and the growth of the immigration flow (half of the population in Buenos Aires was immigrant), tango dance spread into the tenements, family homes and social ballrooms. Dancing tango begins to be accepted as long as, according to a series of institutional ordinances, 'no *corte y quebrada* are done' (its native *criollo* and primitive characteristics). The *compadrito*'s original flexed, lopsided, crouched, crude dance gave way to this new social reality adopting a smoother performance. Meanwhile its music continued to be played to the rhythm of the Habanera.

In 1920 tango definitively abandoned the Habanera rhythm, giving its place to the *marcato en cuatro*. Surprisingly, the 'contributed' gestures of the smoother and more paced tango was mimicked in the isochronous musical pattern of the *marcato en cuatro*.

That is, the gestural change of the dance (1910) anticipates the gesture of the musical marking (1920). Gobello's hypothesis confirms itself.

Regarding pedagogical implications, this work presented research alternatives that help improve the way in which we carry out the observation, study and analysis of dance based on walking its music.

For example, by putting procedural knowledge and objective analysis in dialogue, we indicate a path to study the experience of movement according to the different 'moments' and types of energy that arise during the phases of each step and contextualize them metrically.

The methodological development and analysis here presented reinforce the pedagogical conceptions that support a multimodal-transdisciplinary approach to the teaching and learning of dance.

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