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Monitoring of the center of pressure in unipedal support in karate.

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Abstract

Stabilometry is a technique for analyzing posture based on recording the oscillations of a subject's center of pressure (COP) on an instrumented platform. Under unusual or destabilizing conditions, maintaining postural activity requires the establishment of rapid motor reactions. In this context, we proposed to do the biomechanical monitoring of the stability of two elite karate athletes of different specialties during the execution of an attacking movement of the foot. The analysis carried out on the evaluation of the equilibrium capacity by stabilometric measurements showed different trends in the evolution of the COP. This work could find many applications for the study of behavioral changes occurring with age, both for the detection of young talent and for the monitoring of seniors.

I. Introduction

Dynamic stability monitoring is an analytical technique that was originally developed to quantify balance disorders by recording the oscillations of the COP on an instrumented platform (Visser et al., 2008, p. 2427). The COP is the point of application of the reaction force of the ground resulting in a plane parallel to the surface of the platform (Ouaknine, 2000, p. 2) and whose position makes it possible to assess the stability of the subject during physical activities (Arkov et al., 2009, p. 233). Under unusual or destabilizing conditions, maintaining postural activity requires the development of rapid motor reactions (Cesari and Bertucco, 2008, p. 355).

The reaction time is the latency time between the appearance of the auditory, visual or tactile stimulus and the response to that stimulus, while the speed of execution is rather the speed with which the movement is executed. The reaction time and speed depend on several factors: the level of performance of the athlete considered, the initial posture, the movement he must perform. The measurement of reaction time and speed as well as stability made it possible to compare and classify athletes of various specialties at different levels of performance (Vaghetti et al., 2007, p. 82), and also to evaluate the new types of exercises that are coming to emerge in sports training (Sarabon and Omejec, 2007, p. 998) and functional rehabilitation (Mercer et al., 2009, p. 103). Inertial measurements have recently made it possible to better refine these values compared to those obtained only by video analysis (Gouwanda and Senanayake, 2010, p. 1378).

In many sports, an athlete's level of performance depends on his or her abilities for spatial and temporal orientation, balance and reaction. The capacity for spatio-temporal orientation makes it possible to modify the position and movement of the body in space and time, in relation to a defined field of action. The ability to balance is about keeping the body in a balanced position or restoring balance after a given action. The reaction capacity makes it possible to react by a motor action to a given signal. Any active or passive variation in posture is accompanied by the implementation of automatic compensation devices to preserve or restore the body's balance. For Chinese martial arts (Gorgy et al., 2008, p. 636), practitioners control their balance primarily with the ankle joint by reducing the displacement of the COP in the medio-lateral and antero-posterior directions. The displacement of the COP of subjects not practicing martial arts is more pronounced in the direction of the front.

The classical approach to postural control distinguishes two strategies for restoring balance: that of the ankle and that of the hip. In the first, the subject behaves like an inverted pendulum oscillating back and forth around the axis of the ankles by activation of the appropriate muscles (Senanayake, 2010, p. 307). In the second, the position of the subject's center of mass is affected by the rotation of the trunk around the pelvic axis (Oullier et al., 2003, p. 189).

In this work, we present the results obtained on the unipedal balance of two elite karate athletes of different specialties during the execution of attacking movements of the foot in the mae-geri technique.

II. Method and Materials

1. Participants

The study was performed on two elite athletes in karate, one specialist in kumite and the other in kata. These athletes performed the attacking movement of the Mae-Geri foot in front of a target placed at trunk level on a mobile stand. The evolution of the COP of each athlete was determined for the 4 stages of the movement (armed, attack, return of strike and setting of the foot). The characteristics of our sample are shown in Table 1:

Table 1. Sample characteristics

	Athlete	
	Kumite specialist	**Kata specialist**
Age (ans)	24	22
Weight (kg)	75	68
Height (cm)	178	172

2. Materials

The schematic diagram and the picture of the stabilometric platform designed and tuned for the needs of the experiment are given in figure 1. These are two square plates assumed to be infinitely rigid. On the lower one, which serves as a frame, three load cells have been bolted so that their end forms an equilateral triangle. At these ends, steel balls 2cm in diameter serve as a support for the second plate. A series of aluminum angles were placed on the bottom plate to serve as a stop for the top one and prevent it from tilting as shown in the diagram seen in section of the device.

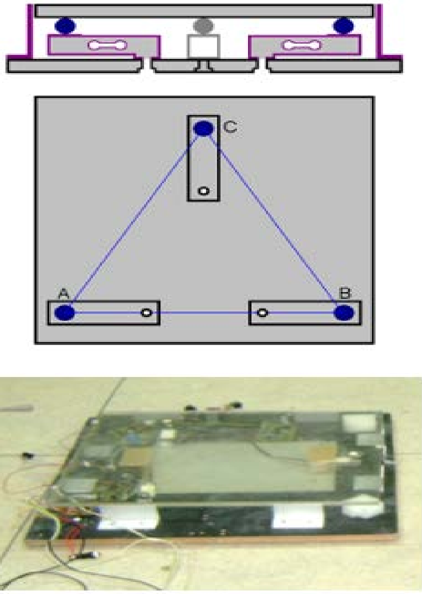

Figure 1. Stabilometric platform.

When empty, the three platform sensors indicate 0N. If a person climbs on the platform, the sum of the forces recorded by the three sensors corresponds to the reaction force. The COP, point of application of the reaction force, corresponds to the point of equilibrium where the combined quantities of the vertical forces and the distances of the vertical forces and of the distances COP - point of application of the forces are equal to on both sides: it is the barycenter of the vertical components of the reaction forces measured by the platform.

The data was acquired using a Daqboard-1000 card from IOTECH which has a 16-bit analog-to-digital converter and 16 multiplexed analog inputs. The sampling frequency has been set at 1 kHz, which is more than sufficient for this type of application. This card is inserted on the motherboard of the central unit of a PC. A special cable connects it to a multi-connector on which the connecting wires of the conditioners of the various sensors are attached. Dedicated software is used to manage the transmission and digital conversion of signals from the sensors.

3. Design and Procedure

In karate, Mae-Geri is the most natural kick of the many that results from the high mobility of the hip. In the variant shown schematically (Habersetzer, 2004, p. 443) in figure 2, the striking surface follows the line straight towards its target and the movement takes place in 4 successive steps from an initial posture (a). These are the armed (b), the strike (c), the return of the leading leg (d) and the landing of the leading foot forward (d).

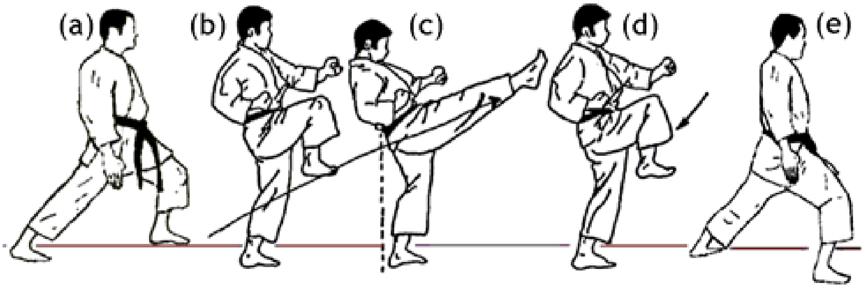

Figure 2. Decomposition of the mae-geri movement.

In the first step of the experimental procedure, we considered the voltage at the output of the accelerometer placed on the leading foot. To interpret the shape of the spectrum obtained, we associated it with the video images relating to the movement performed as shown in figure 3.

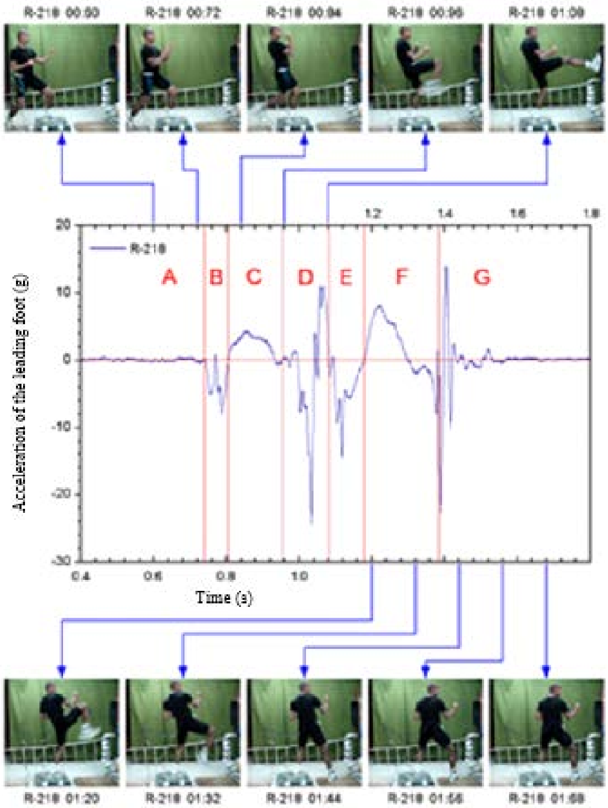

Figure 3. Spectrum correlation of the foot accelerometer – video.

We have divided this graph into 7 parts. In stage A, which is the weight transfer forwards, the acceleration is almost zero and the foot hardly moves. In stage B, the athlete shoots his weapon and the negative acceleration represents the push.

Stage C characterized by positive acceleration represents the army. We see that the acceleration of the foot at the end of this step is canceled out and corresponds to a stopping time of the foot at the end of the step. During stage D associated with the attack the negative acceleration at the start represents flexion of the hip. The foot oscillates on the spot. The positive acceleration peak corresponds to the extension of the knee, followed by the impact which is associated with zero acceleration at the end of the stage. The kickback step F is characterized by a positive acceleration at the start and then a negative acceleration at the end where the athlete brakes his movement. Stage G, which represents the landing, is characterized by a second positive peak and an acceleration.

The identification of these stages serves mainly to delimit the temporal scale: the signals being taken from the various sensors at the same instant, it becomes possible to follow the evolution of the COP according to the movement performed by the athlete. The position "G" of the COP can be determined with respect to the geometric center "O" of the three-support points A, B, C endowed with the respective weights P1, P2 and P3 as shown schematically in figure 4. These three weights are those indicated by the arranged load cells which equip the stabilometry platform, and the barycenter G represents the point of the plane onto which the total weight P of the subject is projected. This amounts to writing that:

$$P = P_1 + P_2 + P_3 \tag{1}$$

$$\overrightarrow{OG} = \frac{P_1 \times \overrightarrow{OA} + P_2 \times \overrightarrow{OB} + P_3 \times \overrightarrow{OC}}{P_1 + P_2 + P_3} \tag{2}$$

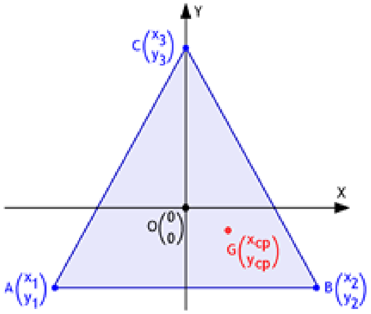

Figure 4. Coordinates of the pressure center and the supports.

In the Cartesian coordinate system (O, x, y), the x axis provides access to the subject's lateral oscillations (from right to left) while y gives access to the subject's back and forth oscillations. In this diagram, the origin O is taken at the level of the geometric center of the equilateral triangle, which is also the point of intersection of the medians at a third of their length. Under these conditions, the components Xcp and Ycp of the COP in the reference (O, x, y) are given by the relations (3) and (4). Note that these values depend only on the indication of the load cells and the dimension of the stabilometric platform.

$$X_{CP} = \frac{a \times (P_1 - P_2)}{2 \times (P_1 + P_2 + P_3)} \quad (3)$$

$$Y_{CP} = \frac{a\sqrt{3} \times (2 \times P_3 - P_1 - P_2)}{6 \times (P_1 + P_2 + P_3)} \quad (4)$$

III. Results

Figure 5 represents the voltage at the output of the load cells arranged under the plate of the stabilometric platform for the mae-geri movement performed in a conventional manner by the first athlete against a target. The front cell corresponds to the solid curve, the left one to the dotted curve and the right one to the drawn curve.

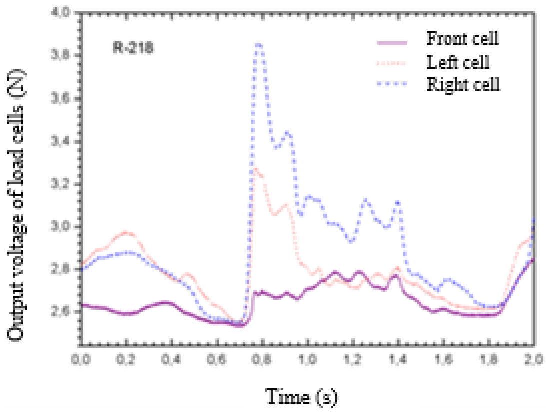

Figure 5. Signals relating to the 3 load cells.

The downforce response determined from the load cell signals was correlated to the video images as shown in Figure 6. At the start of the movement there is first weight transfer to the rear leg. This step represents the tensioning of the muscles involved in the movement in order to create a propulsive force. Then comes the step of transferring weight to the front leg represented by the peak that appears. During both cocking and attacking stages, the weight is gradually distributed between both legs even though the athlete is on a single leg support. At the end of the movement most of the weight is transferred to the front leg and the athlete is in Bipedal support.

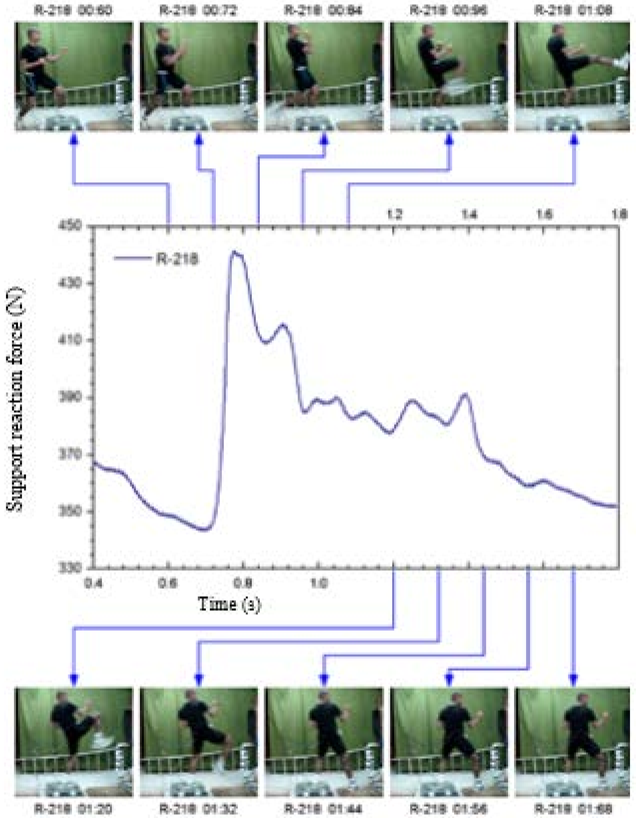

Figure 6. Correlation "support reaction spectrum" - "video images".

Figure 7 shows the spectrum of the coordinates of the COP deduced from formulas (3) and (4) from the signals of the load cells. The COP at the start of the movement shifts slightly to the back and to the left, then it shifts slightly to the right forward: there is a transfer of weight to the front leg. The "armed" phase is characterized by the displacement of the COP to the right and to the rear. The COP then moves to the left and forwards until it is almost back to the starting point. It should be noted that the COP in this athlete only moves over an area of 4 cm^2, thus denoting a high quality of balance.

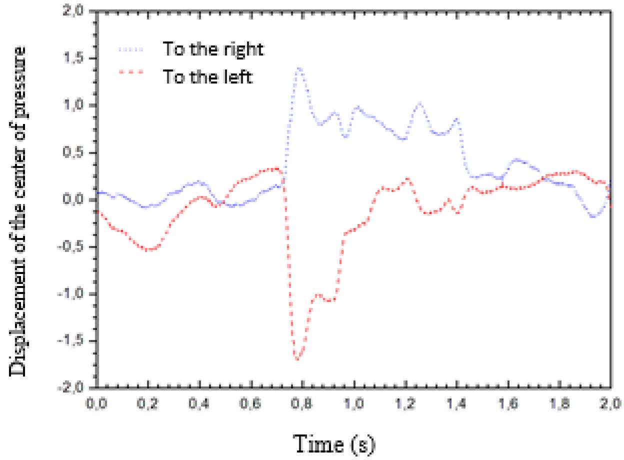

Figure 7. Evolution over time of the abscissa and ordinate of the center of pressure of the specialist in Kumite.

Figure 8 shows the trajectory of the COP in the plane of the stabilometric platform for the elite athlete specializing in kumite. In the classic condition, the COP at the start of the movement shifts slightly to the rear and to the left. This movement represents the tensioning of the muscles involved in the technique in question. The COP then shifts forward and slightly to the right. The athlete shifts their weight to the front leg, preparing the transition from Bipedal support to single leg support. The armed stage is characterized by the displacement of the COP to the right and to the rear. For the remainder of the movement the COP moves to the left and forward until it is almost back to the starting point.

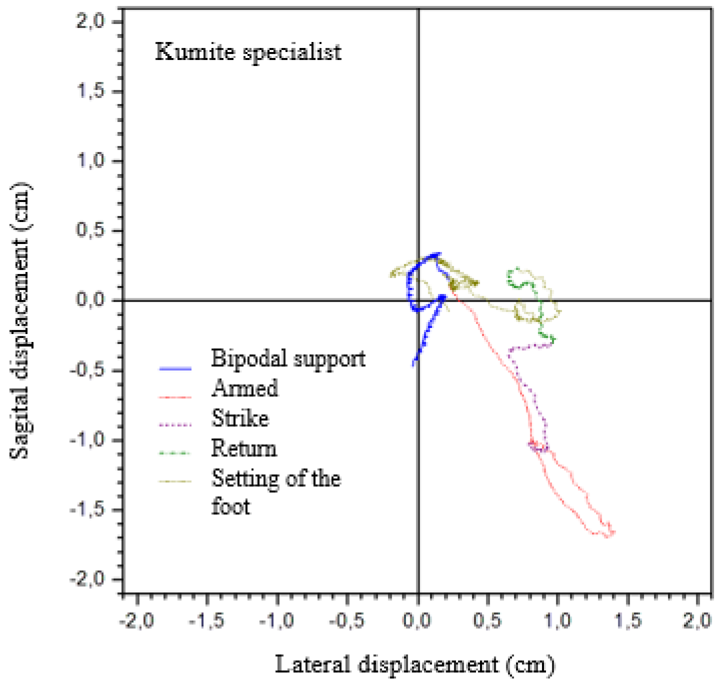

Figure 8. Trajectory of the COP for the specialist athlete in Kumite.

Figure 9 shows the plot of the COP development for the elite kata specialist in the classic target attack condition. The COP at the start of the movement increases in place, then moves back and to the left. This movement represents the step of transferring weight to the front leg, thus preparing the transition from Bipedal support to single leg support. The armed stage is characterized by shifting the COP to the right and back at the start, then forward and to the left. In the attack stage the COP moves slightly forward, then back and to the right. In the kickback stage, the COP continues to move back and right at the start of the stage, then forward and left at the end. The athlete begins the step on the foot which is characterized by the displacement of the COP forward and to the left until it is practically back to the starting point.

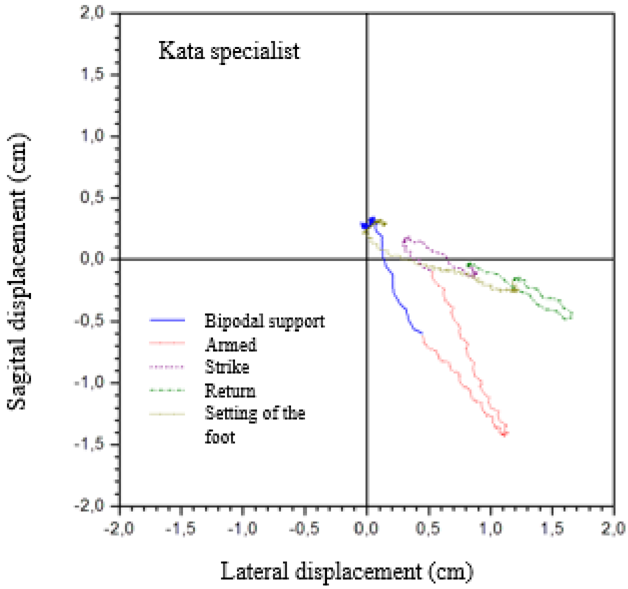

Figure 9. Evolution of the COP for the Kata athlete.

IV. Discussion

The differences observed in the displacement of the COP for these two athletes can be due to the learning process undergone by each, to the conditions of realization of the movement which are familiar to the karateka specialist in kumite unlike the specialist in kata as well as to their morpho-functional qualities. Training in kumite requires the completion of the technique under different conditions (Vencesbrito et al., 2011, p. 1024) (with or without an opponent, in competitive conditions, at maximum power, etc.). In kata, only the technical performance is important, hence the lack of interest in performing the technique in conditions other than empty. It should be noted that despite the differences recorded, the two athletes enjoy a great quality of balance given the small surface in which their COP operates. She is still slightly better in the elite specialist kata athlete. Our results agreed with previous observations (Del Percio et al., 2007 ; 2009, pp. 826-198), suggesting that the kumite karatekas may have a larger sway area than the kata karatekas. Gauchard et al. (2018, p. 24) found that kata and kumite karatekas have different oscillatory techniques, with kata karatekas having a broader sway area and less body sway than kumite karatekas, and indicated that this is more likely the expression of different postural strategies to execute quiet stance depending on the competitive specialization of karatekas. In the context of predictable situations, kata necessitates the management of established and defined transitional phases, while kumite necessitates the management of transitional phases in the context of unpredictable movement situations. The frequent changes of direction and large number of technical positions performed in kata pose a challenge to postural control, and balance mastery is a key determinant of success among all the evaluation criteria. In competition, kata karatekas are penalized if they lose their balance while performing the techniques; mastering static balance, both at the global and segmental levels (Bouisset and Do, 2008, p 353), is thus an additional restriction inherent to kata performance, particularly during the fixed phases of kata, necessitating a reduction in corporal mobility and an increase in postural accuracy. This study looked at what appeared to be one of the most important differences in motor skills between kumite and kata karatekas, namely the requisite postural accuracy and steadiness in kata. Due to the various movement sequences with different goals, the next step may be to set up a more complex approach to balance control.

V. Conclusion

We followed the COP trajectory of two elite karate athletes of different specialties during the execution of an attacking movement of the foot. The analysis carried out on the evaluation of the equilibrium capacity by stabilometric measurements showed different trends in the evolution of the COP. Through this work it appears that this type of instrument usually used for the analysis of the static Bipedal posture can be used for a dynamic analysis with a unipedal support. It could find many applications for the study of behavioral changes occurring with age, both for the detection of young talent and for the monitoring of seniors.

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