
AIKIDO

THE ART OF THE DYNAMIC EQUIANGULAR SPIRAL

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ABSTRACT

Aikido, a Japanese martial discipline, has been labeled “the art of the dynamic sphere.” Its techniques appear to move the body in a “circular” manner resulting in immobilization or projection of a partner. Here we argue that more than spherical motions, aikido techniques describe swirl-like movements, or spirals, similar to the chamber arrangement of a Nautilus shell. When spiral movements are used in aikido, its techniques become very efficient and gentle. We discuss how the principles of the equiangular spiral can be applied to most aspects of aikido training, including stances and sitting postures, bows, stretching exercises, warm-ups, single-person routines to develop balance and mind/body coordination, rolling and falling, partnered techniques of neutralization, projections/throws, and weapons. Not only aikido but also numerous martial arts include equiangular motions in their fighting routines, although martial artists may not be aware of it.

The shell of Nautilus or snail... the elephant's tusk, the beaver's tooth,
the cat's claws or the canary-bird's — all these show the same simple and
very beautiful spiral curve... the equiangular spiral.

— Wentworth-Thompson, 1942

INTRODUCTION

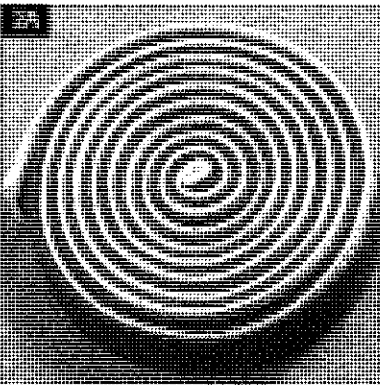
D'Arcy Wentworth-Thompson (1860-1948), a British erudite in the physical and natural sciences, author of *On Growth and Form*, never imagined that his studies on the application of physical and mathematical principles to living forms could help us understand aikido (*aiki* = harmony, *do* = path, the way of). Aikido, a Japanese martial discipline, has been labeled the art of the dynamic sphere. Its techniques appear to move the body in a “circular” synchronized and aesthetic manner resulting in immobilization or projection of a partner. However, more than spherical motions, aikido techniques generate spiral ones. This distinction is not trivial because, when spiral movements are applied to aikido pins and throws, the techniques become much more efficient than when simple circular trajectories are used.

*Photographs courtesy
of A. Espinosa and
G. Paz-y-Miño C.*



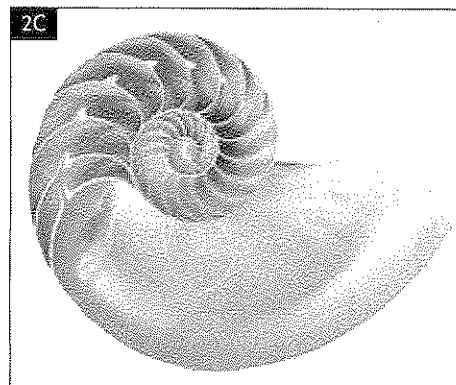
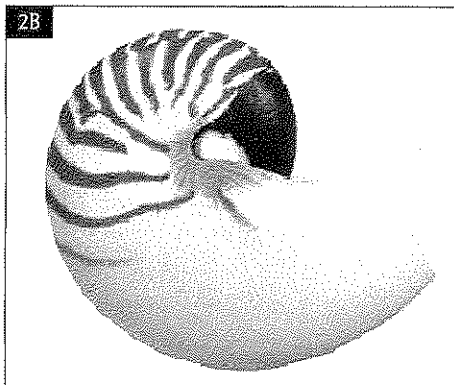
FIGURE 1
THE ONE-POINT OR THE BODY'S
CENTER OF BALANCE/ROTATION.

FIGURE 2
2-A BELT COILED ON ITSELF
ILLUSTRATING A "TIGHT"
EQUABLE SPIRAL OF
ARCHIMEDES.
2-B ENTIRE NAUTILUS SHELL
(EXTERNAL VIEW).
2-C SAGITAL CUT OF A NAUTILUS
SHELL (INTERNAL VIEW).
THE CHAMBERS FOLLOW THE
DESIGN OF AN EQUIANGULAR
SPIRAL OF DESCARTES.
THE LIVING ANIMAL
RESIDES IN THE NEWEST
AND LARGEST CHAMBER.



WHAT DO THE NAUTILUS SHELL AND AIKIDO HAVE IN COMMON?

The equable spiral of Archimedes, illustrated by the way a martial artist coils his belt on itself (Figure 2A), although fascinating for its simple geometry, is as unusual in nature as it is unusual to find perfect spherical anatomical structures or circular motions (no matter how "circular" they may appear!). However, it helps us to understand the properties of its more popular relative, the equiangular spiral of Descartes, illustrated by the structure of a Nautilus shell (Figures 2B and 2C), a beautiful marine mollusk. All natural designs — such as the Nautilus shell, the human cochlea in the inner ear, our teeth and nails, the arrangement of scales in a pinecone, the movement pattern of a tornado, the bull's horn or deer's antler, as well as the aikido techniques discussed in this article — show the same equiangular design (see supplement 1). Why?



As the reader will discover in this article, perhaps a more accurate definition of aikido should be the art of the dynamic equiangular spiral. Here we discuss how the principles of the spiral can be applied to most aspects of aikido training, including stances and sitting postures, bows, stretching exercises, warm-ups, single-person routines to develop balance and mind/body coordination, rolling and falling, partnered techniques of neutralization, projections/throws, and weapons.

The dynamic equiangular spiral originates in what aikidoists call the "one-point" (*seika-no-itten*), or the body's center of balance. In biophysical terms, the one-point is the body's center of rotation; it is located about two inches below the navel (Figure 1). When static, the body is stable as long as the one-point remains centered over its support, the feet. If this

center of balance moves beyond its support, the effect of gravity creates a torque that may cause the body to fall, regardless of size, weight, or muscle. The aikidoist does not need to be constantly over his one-point to be balanced, but if off-center he will need a support, even an invisible one such as motion or inertia, to maintain stability. Aikido techniques are based on this principle. If the aikidoist remains as the center of any motion about himself (or about his one-point), he will be able to throw an attacker while maintaining himself in place.

Supplement I SPIRALS IN NATURE

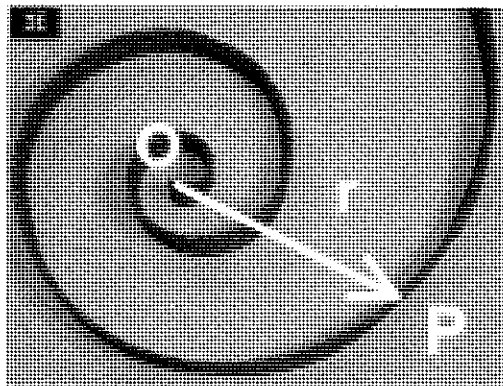
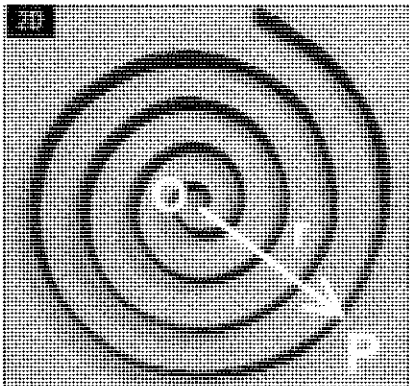
To comprehend the bio-dynamics of aikido's spiral movements we need first to understand simple geometry and physics. Although the material discussed in this article is basic science, it may seem complex to those unfamiliar with these principles. Below, we paraphrase selected statements from Wentworth-Thompson's book and use them to explain how and why spiraling motions can be used in aikido to immobilize or throw an attacker.

A spiral is a curve which, starting from a point of origin (located in a center), continually diminishes in curvature as it recedes from that point, or whose radius of curvature continually increases. The elements of a spiral include (Figure 2D): ❶ the point of origin or pole (O), ❷ the radius vector (r) which is the straight line that, having its extremity in the pole, revolves about it, and ❸ the point (P) which travels along the radius vector, away from the origin, under definite conditions of velocity, thus describing the spiral curve.

Of the several mathematical curves, the two most important to illustrate this article are the equable spiral or spiral of Archimedes, and the equiangular spiral or logarithmic spiral of Descartes. The spiral of Archimedes might be illustrated by the way a martial artist often coils his belt around itself. As the belt is of uniform thickness, so in the whole spiral is each whorl of the same breadth as that which precedes and as that which follows it. If, while the radius vector revolves uniformly about the pole, a point P travels with uniform velocity along it, the curve described will be that called the equable spiral of Archimedes. The radius ($r = OP$), made up of the successive and equal whorls, will increase in arithmetical progression (see, for example, the three equidistant whorls between O and P in Figure 2D). The spiral of Archimedes might also be looked upon as a coiled cylinder.

In contrast, in the equiangular spiral of Descartes, the whorls continually increase in breadth, and in a steady and unchanging ratio. If, instead of traveling with a uniform velocity, the point P moves along the radius vector with a velocity increasing as does its distance from the pole, then the path described is called an equiangular spiral. Each whorl the radius vector intersects is broader than its predecessor in a definite ratio (Figure 2E); thus, the radius vector will increase in length in geometrical progression (note that in Figure 2E there is only one whorl between O and P, and that the distance from this whorl to O is shorter than the distance from it to P). As the spiral of Archimedes in our example of the coiled belt might be looked upon as a coiled cylinder, so the equiangular spiral might be looked upon as a cone coiled upon itself, like in the Nautilus shell (Figures 2B and 2C).

- 2-D THE ELEMENTS OF THE SPIRAL: POINT OF ORIGIN OR POLE O, THE RADIUS VECTOR r , AND THE TRAVELING POINT P. THE READER WILL COUNT THREE EQUIDISTANT WHORLS BETWEEN O AND P.
- 2-E THE GEOMETRICAL SPIRAL OF DESCARTES, OR EQUIANGULAR SPIRAL. THE READER SHALL COUNT ONLY ONE WHORL BETWEEN O AND P EVEN THOUGH THE LENGTH OF THE RADIUS r IN E IS SIMILAR TO THAT OF THE RADIUS IN D.



The Nautilus shell is an excellent example to illustrate why the equiangular spiral is an efficient way of growing. The presently existing structure is, so to speak, partly old and partly new. It has been formed by successive and continuous increments; each successive stage of growth, starting from the origin (the smallest chamber), remains as an integral and unchanging portion of the growing structure. The shell itself consists of dead material, old and smaller chambers used by the mollusk in earlier stages of its development.

Aikido techniques are designed exactly in the same fashion as the Nautilus chamber arrangement. A forward roll (such as the one illustrated on the cover page of this article), for instance, originates in a small swirl at the level of the aikidoist's hands, and continues in a geometric progression toward the feet. The entire body outlines an equiangular spiral where the feet move with a velocity increasing as does their distance from the hands. Just like the eye of a typhoon, which is always peaceful, so are the hands of the aikidoist while rolling forward, however, the feet move with great acceleration as they distance from the hands (see Supplement 2). Thus, the forward roll illustrates the essence of aikido's equiangular motions.

Supplement 2

THE PHYSICS OF THE EQUIANGULAR SPIRAL

If an aikidoist projects an attacker into a spiral path with the aikidoist's one-point as the center of the rotation, the attacker will fly off the center at a tangent to the aikidoist's body, describing an equiangular trajectory in respect to the aikidoist's one-point. After exerting an initial force to start the throw, the aikidoist will spin at a constant rate and, therefore, having no change in speed, he will have no angular acceleration (like the eye of the typhoon). In contrast, the attacker will experience significant centripetal force with a velocity increasing in relation to the distance from the aikidoist's one-point.* This can be described according to the equation:

$$F = m (v^2 / r)$$

Force = mass x (velocity squared divided by the radius of the spiral)

A 160-pound attacker being thrown by an aikidoist at 10 miles per hour, with a radius of 20 inches in respect to the aikidoist's one-point, will exert an impressive centripetal force of:

$$F = (72.72 \text{ kg}) (4.5 \text{ m/sec}^2 / 0.5 \text{ m}) = 2945 \text{ Newtons} = 661 \text{ pounds}$$

If falling out of control, the 160-pound attacker will hit the ground with a force equivalent to four times his normal weight. Do you see why aikidoists prefer to roll rather than to fall? This explains how a small individual can deflect, redirect, and project a far larger and stronger attacker. By staying offline, using the tools of leverage, rotation, and the power of the equiangular spiral, the smaller person – if moving properly – can have an advantage over a larger attacker.

* Note that, for simplicity, in this example we do not include all the factors that characterize the movement of an attacker such as his angular acceleration with respect to the aikidoist's one-point, his friction against the mat (or the aikidoist's body if contact occurs), or the inertia resulting from the technique applied to his body. For details, see Shifflett (1999), and Watanabe and Avakian (1997).

THINKING AND MOVING "EQUIANGULARLY"

Although the forward roll clearly illustrates the equiangular nature of aikido's motions, the application of this concept to other aspects of aikido training might not be that evident to most students. Realize that not only every arm lock, wrist bend or break fall, but also every posture, bow, stretch exercise, cut with a wooden sword (*bokken*) or poke with a wooden staff (*jo*), describe an equiangular trajectory. This is because, when the joints of the body interact and move in different directions, they simultaneously create small and large spirals. In consequence, there is not only one equiangular spiral at work when an aikido technique is in progress, but multiple ones interconnected in a three dimensional environment.

To improve the efficiency of aikido techniques the student should think and move "equiangularly." Here are some tips that may help you achieve this goal:

- ❶ discover the location of most of the equiangular spirals in both your and the attacker's anatomy, particularly where the centers of rotation of each spiral are located (i.e., the joints);
- ❷ understand how your own and the attacker's spirals are interconnected when in motion;
- ❸ determine the directions in which you should move or apply an aikido technique in respect to the attacker's movements (i.e., toward the spiral's point of origin or away from it); and
- ❹ allow your body to flow naturally in the direction that the dynamic spirals dictate.

Figure 3 illustrates these points. Note that the relative position of the one-point in both aikidoists is indicated with a white circle (lower abdomen). Ultimately, the defender (right), whose one-point will become the center of the main equiangular motion, will assure control of both the technique and the attacker (left). The points of origin or centers of rotation/movement of the remaining minor (secondary) spirals are represented by black dots. The arrows indicate how those spirals must move harmoniously in relation to the defender's and also the attacker's one-points. In Figure 3A the defender redirects the attack (an open-hand strike to the forehead) downwards. Once the deflection is completed, the attacker's one-point moves to a lower level with respect to the defender's (Figure 3B). The neutralization of the attack is successfully accomplished if the defender remains at all times at the center of the spiral motion and his one-point is located (even slightly) above the attacker's one-point.

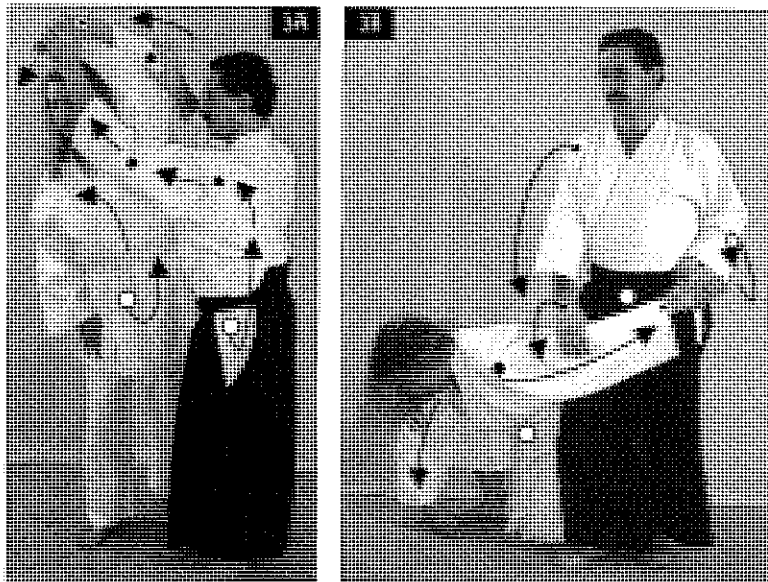


FIGURE 3

THE EQUIANGULAR SPIRAL CONCEPT APPLIED TO AIKIDO. A WHITE CIRCLE INDICATES THE LOCATION OF THE ONE-POINT, THE CENTER OF THE MAIN EQUIANGULAR SPIRAL. BLACK DOTS INDICATE THE CENTERS OF ROTATION/MOVEMENT (THE JOINTS) OF MINOR (SECONDARY) SPIRALS. ARROWS POINT IN THE DIRECTION OF MOVEMENT.

The student will learn how to move in this spiral fashion only if he develops a clear mental image of the geometric progression of an equiangular trajectory. In most immobilizations and pins, for example, the aikidoist should curl the attacker's wrist, elbow or shoulder inward, toward the point of origin of the spiral. However, in numerous single-person routines, or even in projections, the aikidoist should first follow the opposite direction of the spiral, which is outwardly, toward the open course of the coil, in order to initiate big motions of the body and generate inertia for throwing. Then the aikidoist should bring the attacker toward the aikidoist's one-point to create the necessary equiangular direction and make the attacker fly off the center of rotation (centripetal force).

TECHNICAL SECTION

In the following figures we indicate how to apply the concept of the equiangular spiral to aikido stances, sitting postures, bows, stretching exercises, single-person routines to develop balance and mind and body coordination, rolling and falling, techniques of neutralization (mostly immobilizations), projections/throws, and weapons. The material presented below is by no means complete; nonetheless, it does cover essential aspects of aikido training. The photos illustrate cases where the equiangular spiral can be easily visualized. It will be up to the student, however, to detect equiangular motions in other training scenarios:

FIGURE 4 - Standing

- 4-A The aikidoist focuses his mind in the one-point (white dot), the body's center of balance. Centers of secondary spirals are shown at the shoulder level. The arms, with the elbows and hands slightly bent inward, naturally follow an equiangular direction (down/in).
- 4-B The aikidoist bows from the one-point (center of the main equiangular movement) and places the palms lightly over the thighs, close to the knees.
- 4-C Readiness posture, lateral view. The arms are partially extended following the direction of the equiangular spirals (centered in the shoulders) forward and upward. The entire posture relies on its connection with the one-point.
- 4-D Readiness posture, frontal view. The aikidoist "hides" himself behind the hands, protecting his face and torso.

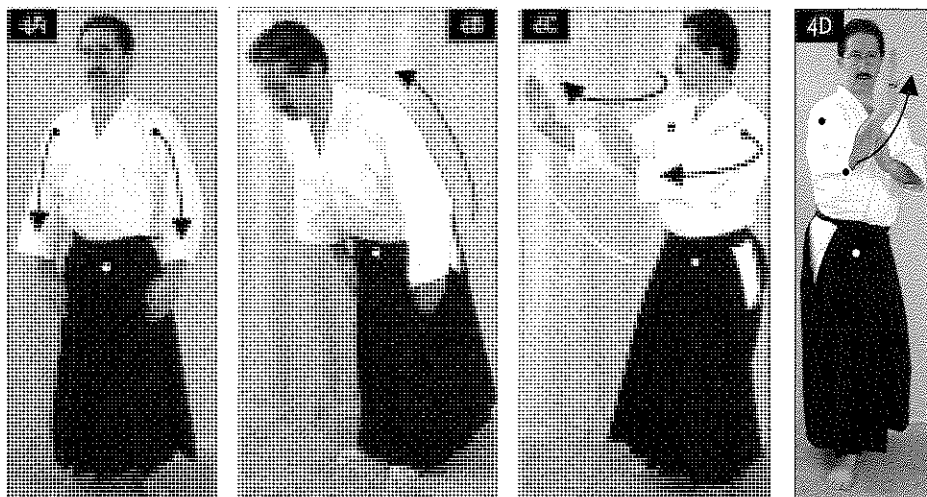


FIGURE 5 – Sitting

5-A Seiza (formal aikido sitting posture).

The equiangular direction of the arms is even more evident in seiza than in the standing posture shown in Figure 4-A (above). Black dots at the elbows and wrists indicate the centers of minor equiangular spirals.

5-B Seiza bow. A clear illustration of the equiangular direction followed by the torso, which always remains connected to the one-point (white circle). Note the centers of the secondary spirals in the shoulder and elbow (black dots).

5-C Cross-legged sitting, frontal view. The aikidoist feels the centers of the equiangular spirals not only in the forelimb joints but also in the crossed legs (particularly in the hip and knee-joints).



5-D Cross-legged sitting, lateral view. Note the directions followed by the numerous equiangular spirals. In relaxation, this pyramidal shape adopted by the aikidoist's body gives him great stability.

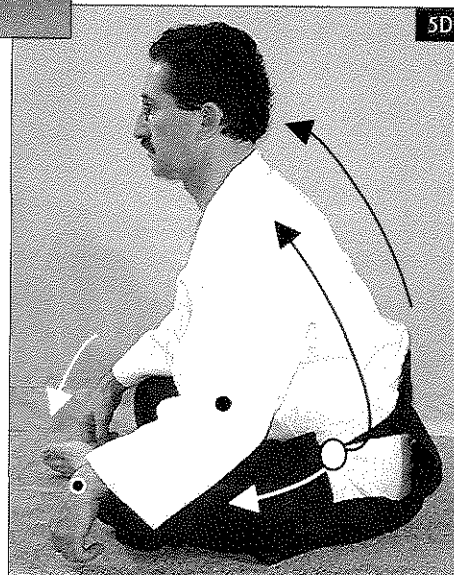
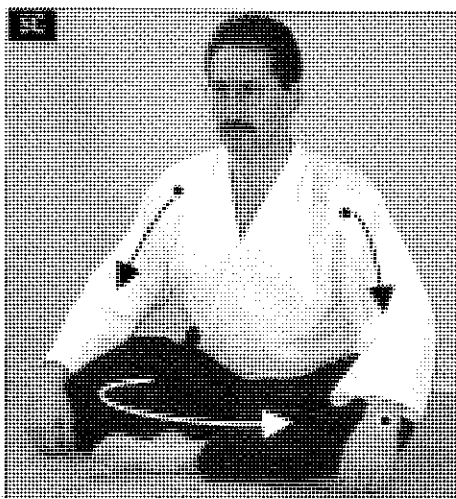
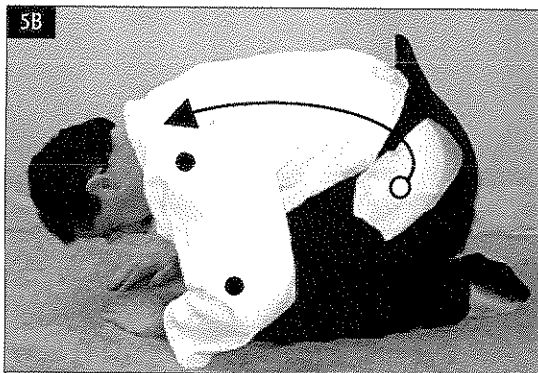


FIGURE 6

Leg Stretches

6-A Open legs. Both legs have a very wide equiangular orientation centered in the one-point.

6-B The aikidoist bends forward from the one-point (not the shoulders!), keeping the back straight and the toes up; once in this position, he stretches the arms forward, feeling the centers of equiangular spirals first in the one-point, and then in the shoulders, elbows and wrists.

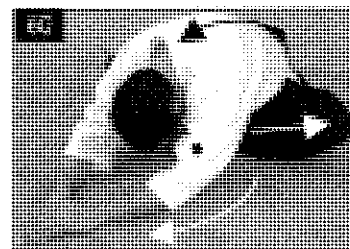
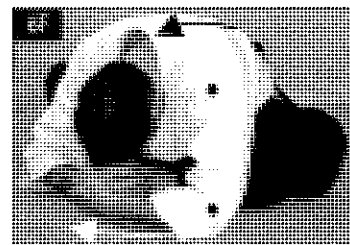
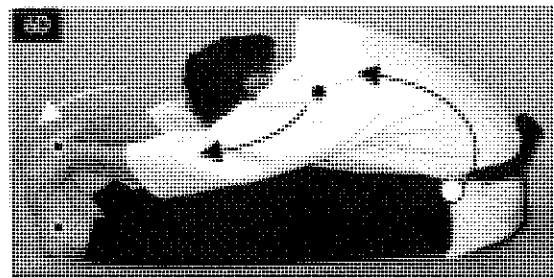
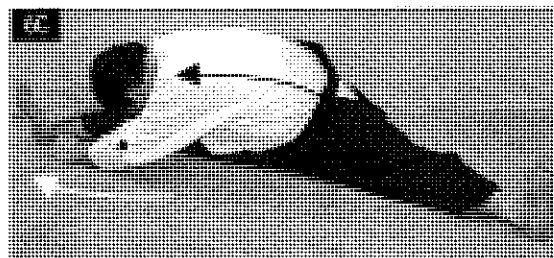
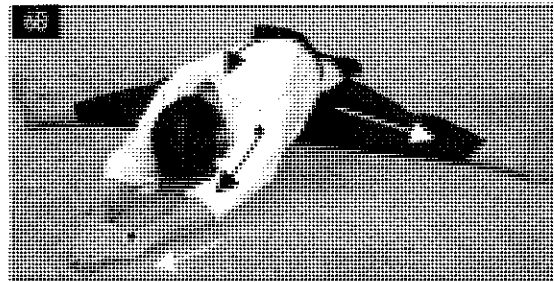
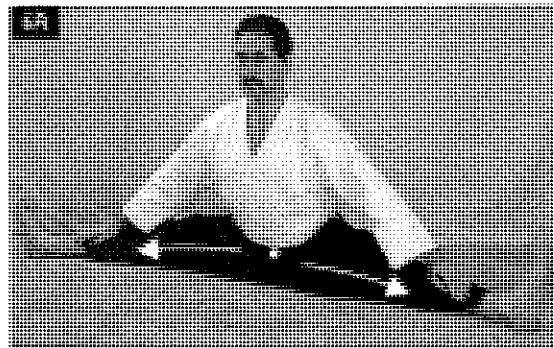
6-C Same as in B, but now the aikidoist brings his chest (not his head!) toward one of the knees and continues feeling the equiangular spirals in the shoulder, elbow and wrist.

6-D Legs extended, heels together. The aikidoist bends forward from the one-point, bringing the chest toward the knees. The equiangular motion should be smooth and the entire body must remain relaxed.

6-E Soles of feet in contact and drawn into the hips. Various equiangular directions are shown by the arrows.

6-F The aikidoist bends forward from the one-point, bringing the chest to the feet.

6-G Once in the position shown in F, the aikidoist stretches the arms forward. The diverse equiangular directions followed by the torso (forward), legs (out), and arms (forward/in), are indicated by the arrows.



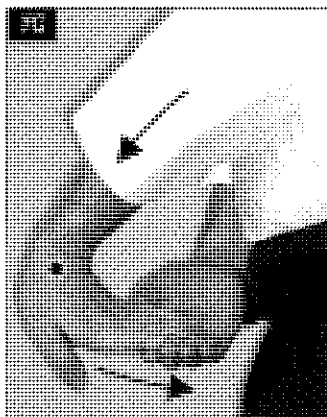
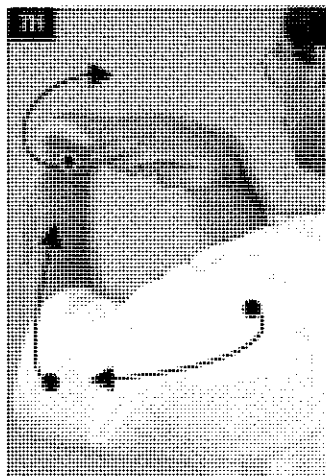
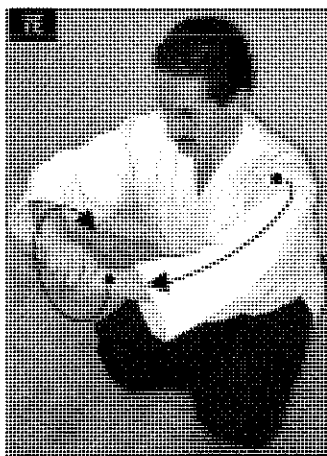
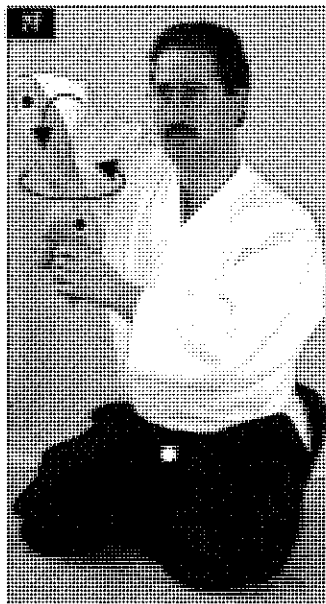
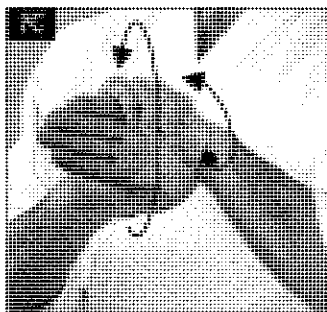
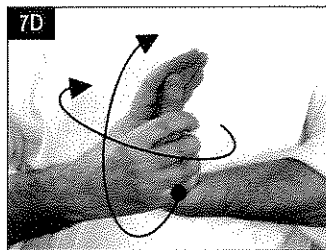
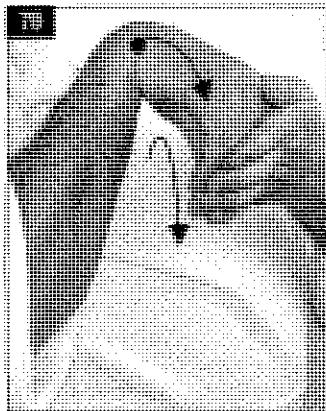
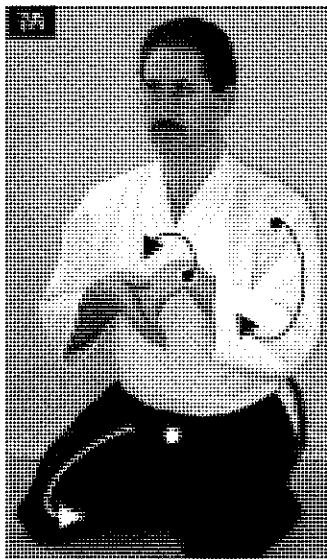


FIGURE 7

Wrist Stretches From Seiza

7-A Sitting in seiza, the aikidoist stretches the wrists. The centers of the equiangular spirals are indicated by the white (one-point) and black (shoulder and wrist) dots.

7-B Keeping the elbows down and in complete relaxation, the aikidoist curls the fingers inward. The equiangular trajectory is obvious!

7-C The wrist remains close to the chest area while the fingertips point forward (elbows down). One hand grabs the edge of the other hand. Simple relaxation provides enough stretching of the joint in a natural equiangular direction.

7-D Fingertips up. Two equiangular trajectories are indicated by the arrows; if the aikidoist relaxes and allows both hands to fall toward the one-point, the stretch is safe and correct.

7-E By grabbing with one hand the edge of the other and by stretching both arms forward (shoulders down and elbows pointing out!), the aikidoist generates a pleasant equiangular rotation in the wrist.

7-F Elbow pointing to the sky and forearm perpendicular to the ground. The aikidoist stretches the wrist by turning it in. At least two equiangular spirals are evident here: one centered in the elbow and another in the wrist (black dots).

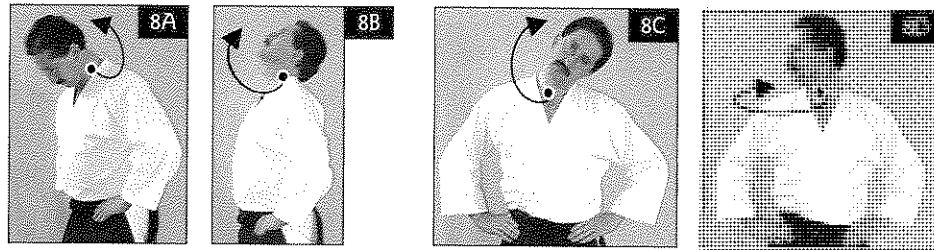
7-G Wrist stretch with the fingertips in the direction of the one-point.

7-H Same as in G, but the fingertips now point to the shoulder.

FIGURE 8

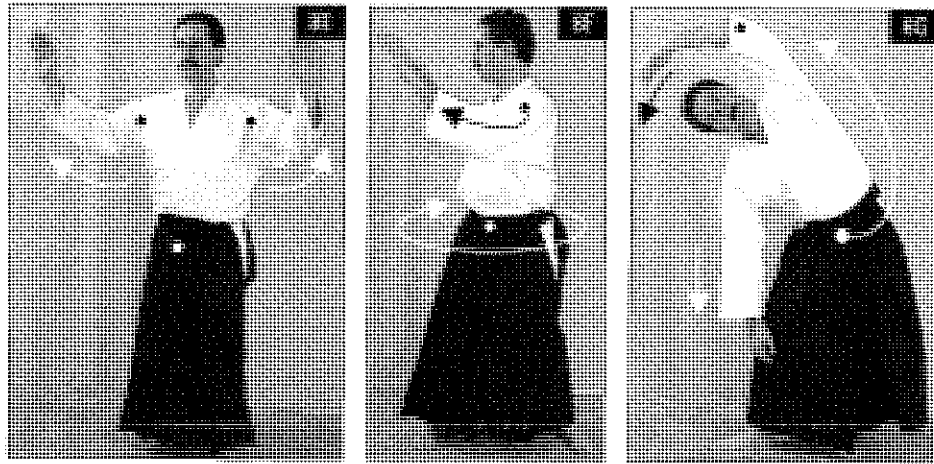
Neck, Shoulders, Arms and Torso Stretches

8-A-D Neck stretches (down, up, lateral and side). The centers of the equiangular spirals are located at the base of the cervical vertebrae.



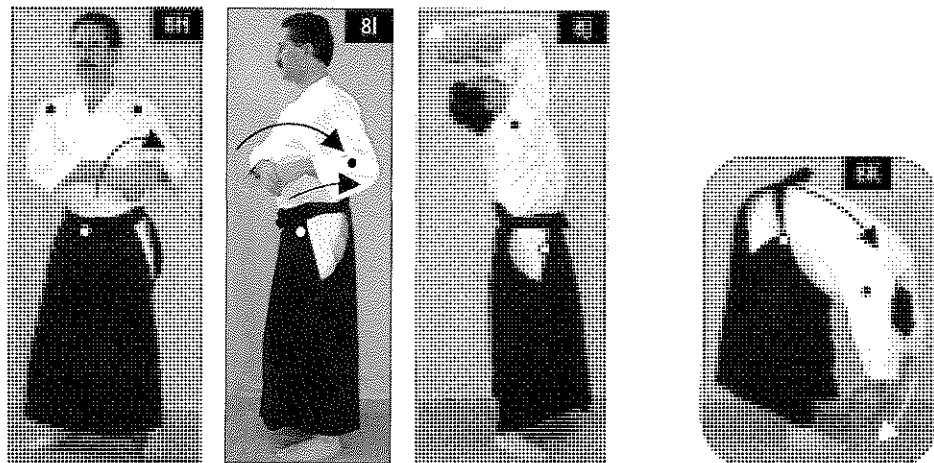
8-E-F From a standing position and with the arms wide open (relaxed shoulders as in E), the aikidoist rotates the torso from the hips toward one side (F) and then to the other. The equiangular trajectory (white arrow) is centered in the one-point and its plane of rotation is parallel to the mat. The arms form their own equiangular spirals.

8-G Lateral stretch of the torso. Note how the torso and arm describe a clear equiangular spiral centered in the one-point.



8-H-I Shoulder and arm stretches. The aikidoist grabs with one hand the dorsal side of the other and gently takes the elbow backward (H, frontal view), keeping the elbow close to the torso and the shoulders relaxed (I, lateral view). Ultimately, the one-point and the elbow remain connected and the aikidoist feels the spiral motion traveling from the one-point to the elbow and vice versa.

8-J-K From a standing position and with the arms up (see the direction of the arm spiral in J), the aikidoist bends forward from the one-point, describing a long equiangular motion (K).



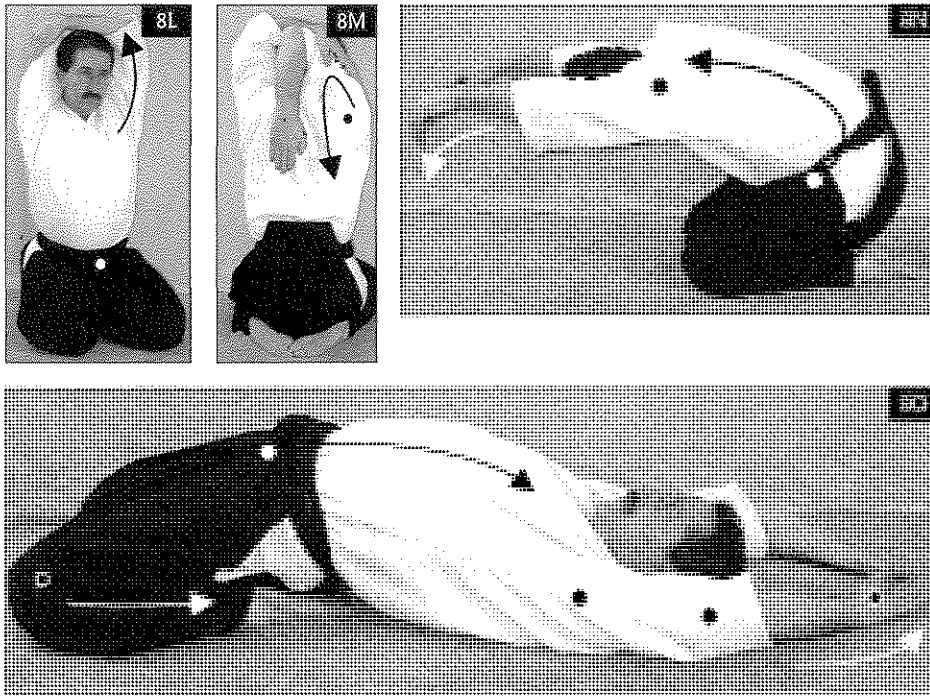


FIGURE 9

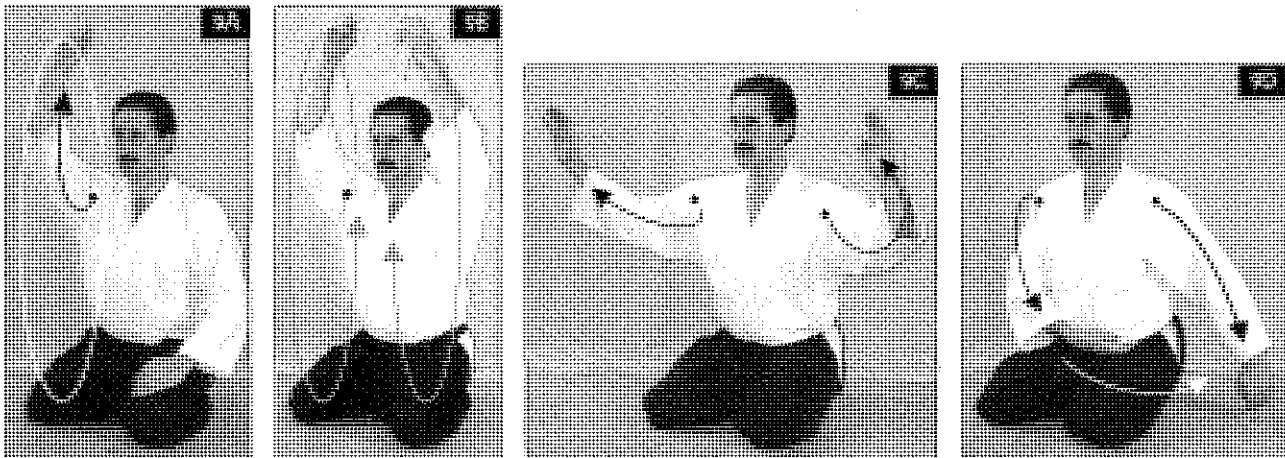
Single Person Exercises to Develop Mind and Body Coordination from Seiza

The following exercises are performed in a completely relaxed state. These routines are designed to keep the mind focused on accurate, delicate movements. While keeping the body steady, the aikidoist feels the equiangular trajectories centered in the shoulders, elbows, and wrists. Series of up to eight repetitions are recommended.

- 9-A Arm "circles." In reality, the hand describes an elliptical trajectory. The arm itself is shaped as an equiangular spiral centered in the shoulder. The aikidoist allows the arm to fall with gravity, then he catches it when the hand reaches the knee level, and takes the arm up again.
- 9-B Same as in A, but with both arms in motion. The body remains calm while the arms move rhythmically. Both inward and outward motions should be practiced.
- 9-C-D Arms wide-open and equiangular spirals clearly visible on each side; fingertips point

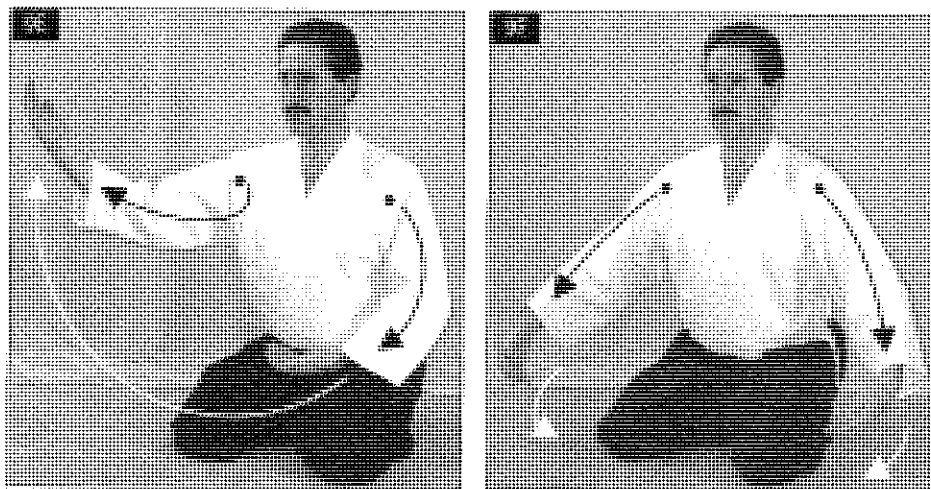
- 8-L-M From seiza. Frontal (L) and posterior view (M) of a tight equiangular stretch of the shoulder joint.
- 8-N From seiza. Long stretch. The equiangular spiral originates in the one-point and continues forward to the arms and fingertips.
- 8-O From seiza. Long stretch backward. Equiangular spirals are evident in the one-point, the entire forelimb and, interestingly, the knee. Complete relaxation is required!

up (C). The aikidoist swings his arms to one side as in D, and then to the other (now, fingertips point down). The arms are moved gently but rhythmically while keeping the rest of the body calm, almost static.



9-E From the position illustrated in E, the aikidoist swings his arms to one side and then to the other. The equiangular trajectory of both arms should be clearly defined.

9-F-G From the position illustrated in F, the aikidoist moves his hands in and places



them in front of the one-point, where they cross, as in G. The fingertips point in opposite directions.

9-H From F, the aikidoist swings his hands forward and up, placing them in front of the face.

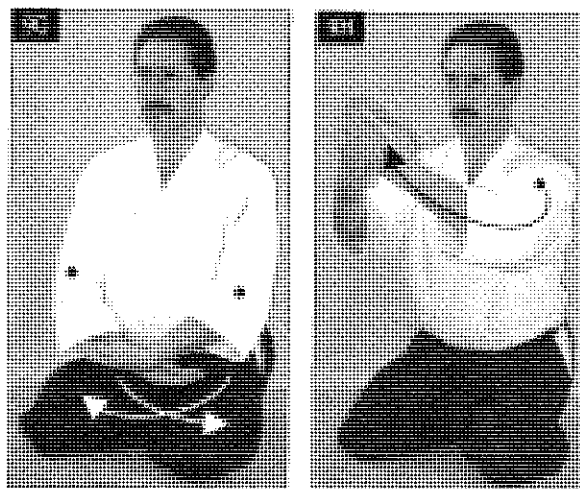


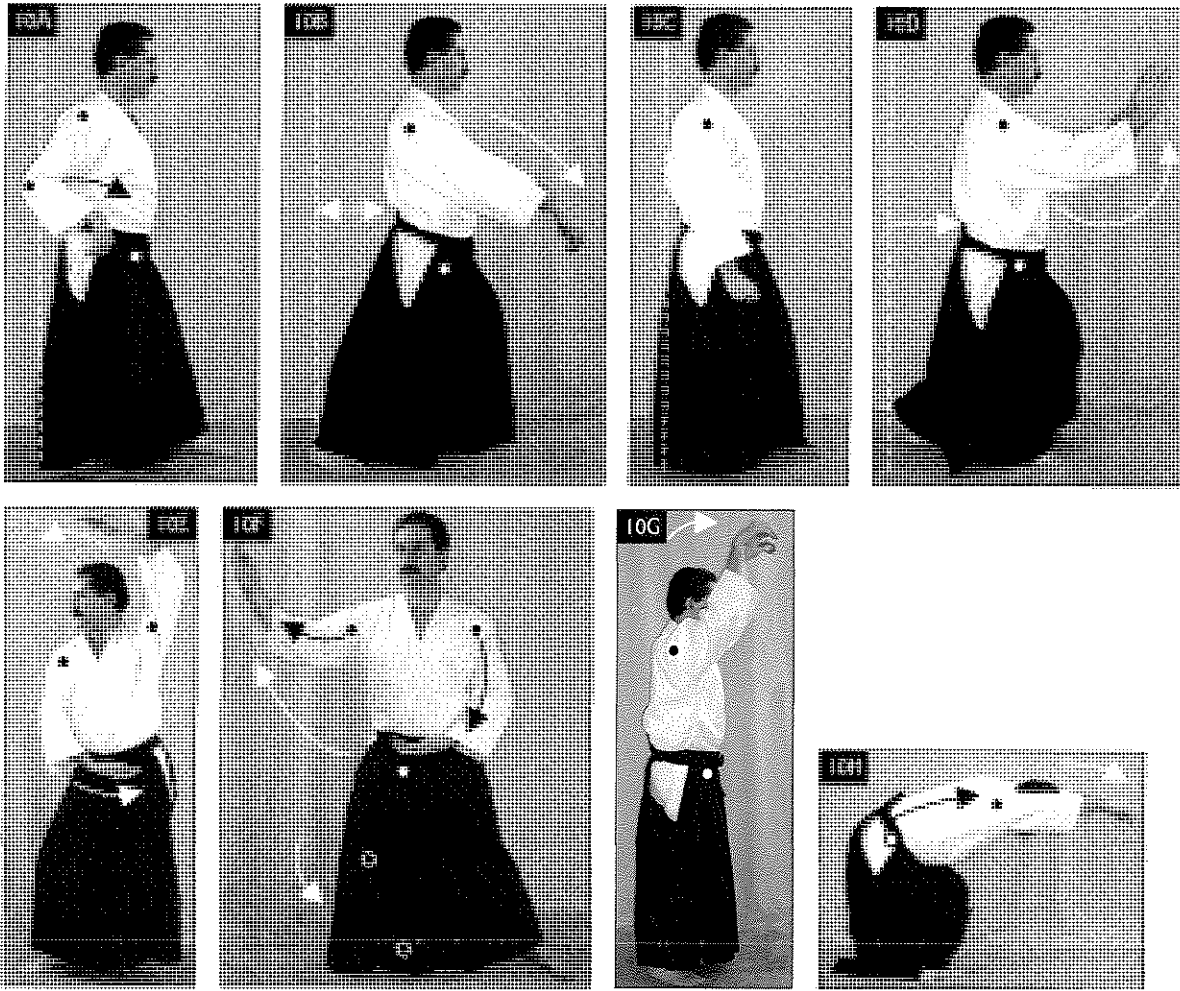
FIGURE 10 - Single Person Exercises to Develop Balance and Coordination, from a Standing Posture

10-A-B Boat-rowing exercises. Hands touch the hips (A). The aikidoist shifts the hips forward while thrusting out the arms (B); then he goes back to the original position. The equiangular spirals are centered in the shoulders and continue along the arms toward the fingertips (pointing forward/down as in B).

10-C-D Arm-swing exercise. First, hands touch lightly the thighs (C), then the aikidoist shifts the entire body forward while swinging the arms forward and up; fingertips extended (D). The equiangular spirals are centered in the shoulders. The entire motion relies on its connection with the one-point.

10-E Both arms follow equiangular trajectories centered in the shoulders and continuing toward the fingertips, which point in opposite directions. The aikidoist turns his head to one side, in the same direction as the upper hand's fingertips; note how one of the feet also points in that same direction. Hands, head, and one-point should be vertically aligned.

10-F Similar to the exercise described in Figure 9-E, but now from a standing position. The aikidoist swings his arms to one side and then to the other. Note that one knee bends while the entire body drops slightly in the direction of the bent knee. The equiangular trajectory of both arms should be clearly visible. Additionally, the aikidoist feels an equiangular connection between his one-point, the bent knee, and the foot.

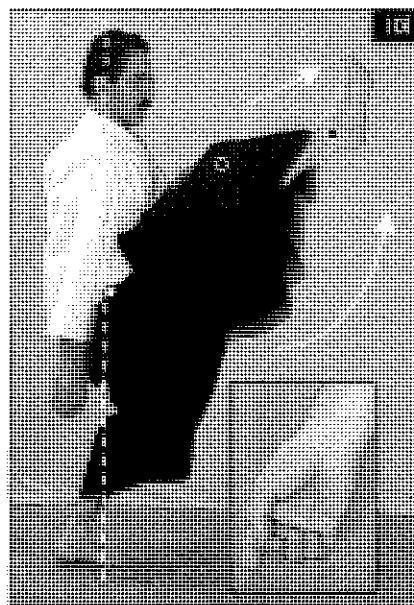


10-G-H From standing with the arms up (shoulders relaxed) and the wrists naturally bent forward (fingertips point forward/down), the aikidoist steps and bends from the one-point (H). The equiangular spiral originates in the one-point and continues forward to the arms and fingertips.

10-I “Front-kick” exercise.

Two equiangular spirals are obvious, one centered in the one-point and the other in the knee; their combination generates impressive power in the technique. To maintain balance, the aikidoist keeps the head, shoulders, elbow, hand, hips (one-point), and supporting leg vertically aligned (white line).

To show complete relaxation, he uses a “trick”: the hands remain gently closed, next to the vertical alignment of the body, with the thumbs slightly touching the middle finger (see detail).



- 10-J-K Knee "walking." The aikidoist describes equiangular motions with each knee step (indicated by the white arrows); he pivots from side to side on alternating knees. Black arrows indicate the forward direction of the knee-walk.
- 10-L Aikido squats, a very demanding exercise. Sitting on his heels, the aikidoist jumps (arrows) while keeping the torso steady and relaxed. Legs must do all the work and knees should remain wide open (this is crucial!). Two equiangular spirals originate in the one point and depart in opposite directions toward the knees, where new spiral trajectories continue toward the feet. The angle of curvature of all these spirals changes when jumping.

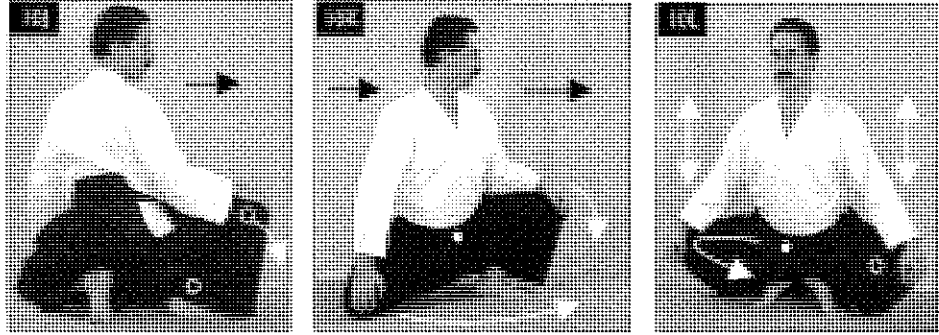
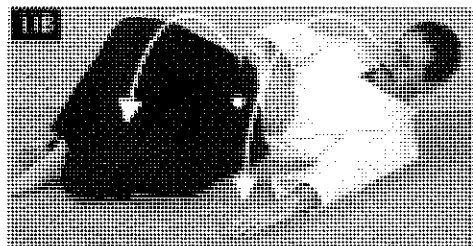


FIGURE 11
Rolling and Falling

11-A Wide-open aikido roll illustrating the equiangular spiral. Quiet rolls are an indication that the aikidoist is correctly performing an equiangular trajectory. The roll starts from standing and, after completion, the aikidoist recovers the standing posture or continues walking. Any deviation from the spiral geometrical progression of a roll will be revealed by the amount of noise the aikidoist makes when rolling.

11-B Break fall. Once rolling as in A, the aikidoist could land on the mat (instead of standing up or continuing walking as indicated in A). Only if the body describes an accurate equiangular trajectory, is the break fall smooth, safe, and painless. Performing a "quiet" break fall, a task almost impossible to achieve, should be the ultimate goal of the student.



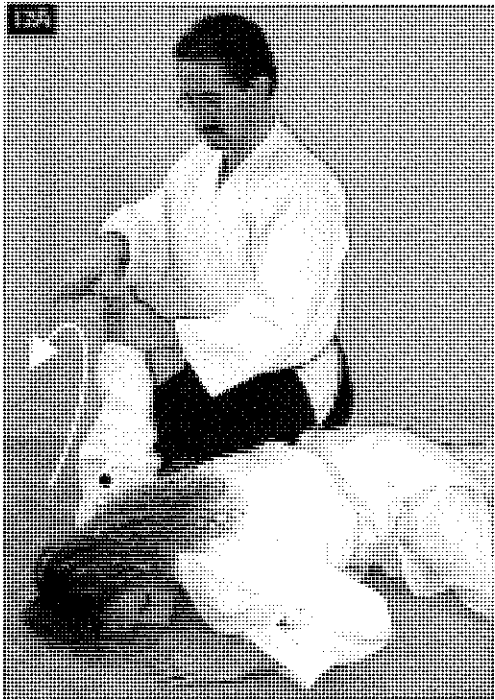
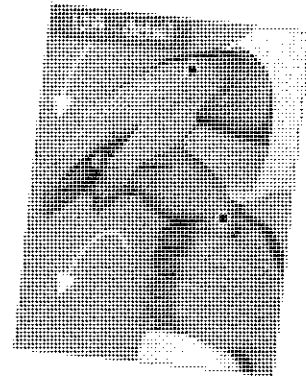
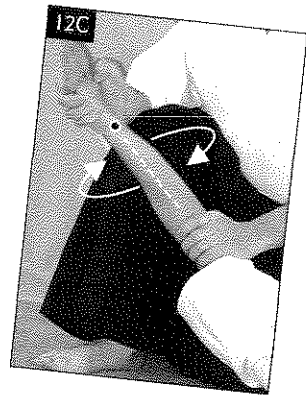
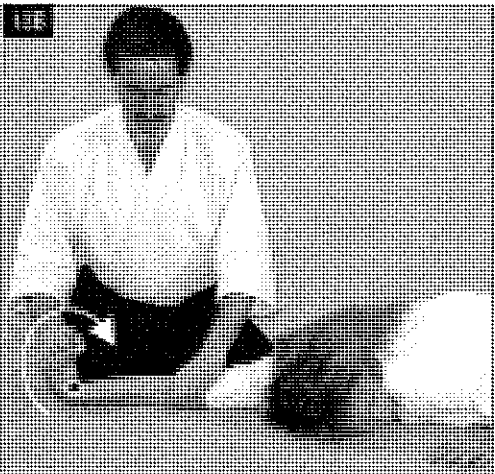


FIGURE 12 - Partnered Aikido Techniques of Immobilization

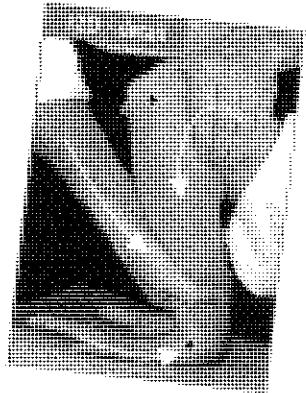
12-A The arm contortion applied by the aikidoist (kneeling) follows an equiangular trajectory centered in the shoulder, which contributes to pin the attacker. Note how the attacker's arm remains perpendicular to the mat. The detail shows how the wristlock is performed; both the aikidoist's (top) and the attacker's wrists describe equiangular spirals.



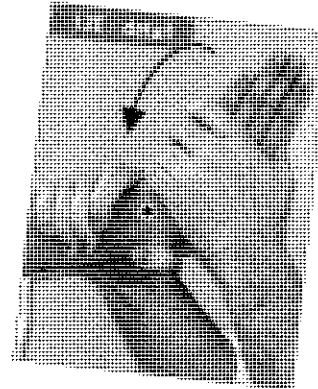
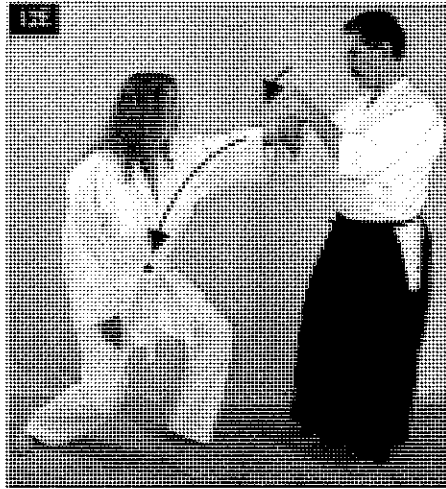
12-B-C The aikidoist (kneeling) holds the attacker's arm firmly against the mat (elbow grabbed) while bending the attacker's wrist/fingers toward her forearm. The equiangular spiral is centered in the wrist (B). A technique alternative to this lock is indicated in C, where the aikidoist holds the attacker's arm firmly against the aikidoist's knee while twisting the hand in the direction indicated by the arrows. In this case, the equiangular contortion takes place in a plane perpendicular to the forearm's axis (line).



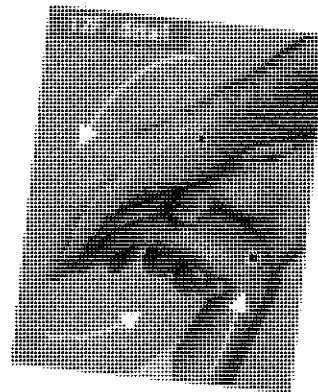
12-D Two equiangular spirals, one in the wrist and the other in the elbow, are shown in this elegant technique. The aikidoist controls the elbow and wrist while applying gentle pressure in the direction of the bent wrist.



12-E While keeping the attacker's fingers pointing up, the aikidoist bends the attacker's wrist toward her one-point. The equiangular trajectory of the technique, which connects the wrist with the elbow, shoulder and one-point, forces the attacker to kneel.

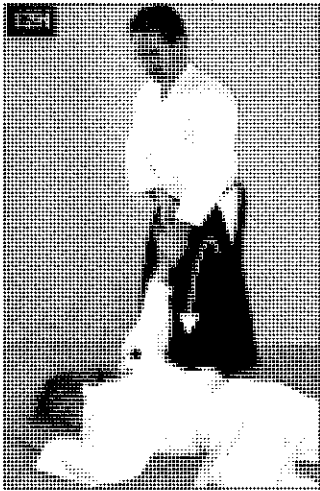


12-F The aikidoist (standing) bends the attacker's wrist inward and down, in the direction of the one-point. The spiral motion centered in the wrist (detail) forces the attacker to fall.

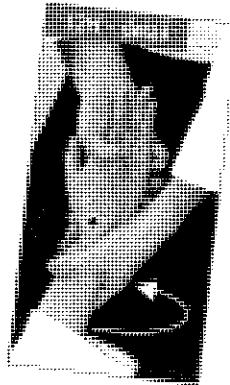


12-G Same as in F, but now after the attacker has been thrown into a break fall. Once the fall has been completed, the aikidoist (kneeling) continues bending the attacker's wrist in an equiangular trajectory (aimed to the attacker's one-point) to maintain the pin.





12-H The aikidoist (standing) keeps the attacker's arm stretched and perpendicular to the mat while creating slight pressure down and in, toward the shoulder (center of the main equiangular spiral). The detail shows how the wrist should be twisted in a perpendicular plane (equiangular direction) with respect to the arm's axis.



12-I "Three palms up" pin. This complex and beautiful aikido pin relies on, at least, three equiangular trajectories applied to the arm: one in the direction of each of the aikidoist's hands (down and in), and another in the direction of the attacker's shoulder. This is a sophisticated example of the equiangular concept applied to aikido: the three spirals converge into a major center of rotation, the attacker's shoulder.

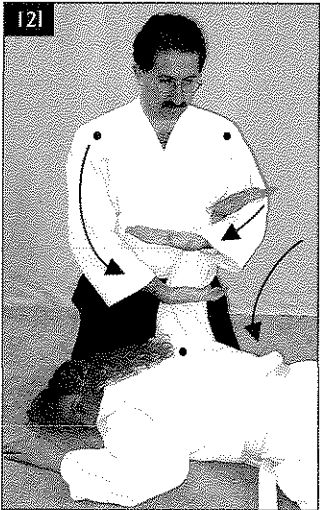
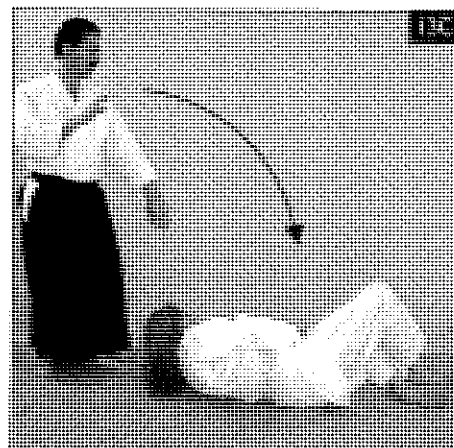
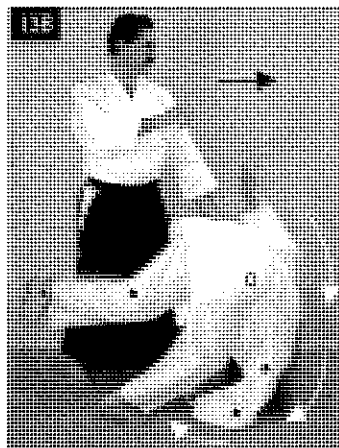
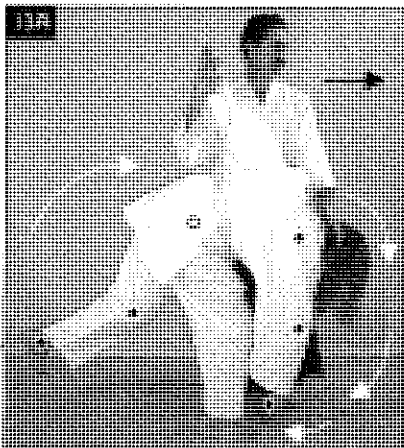
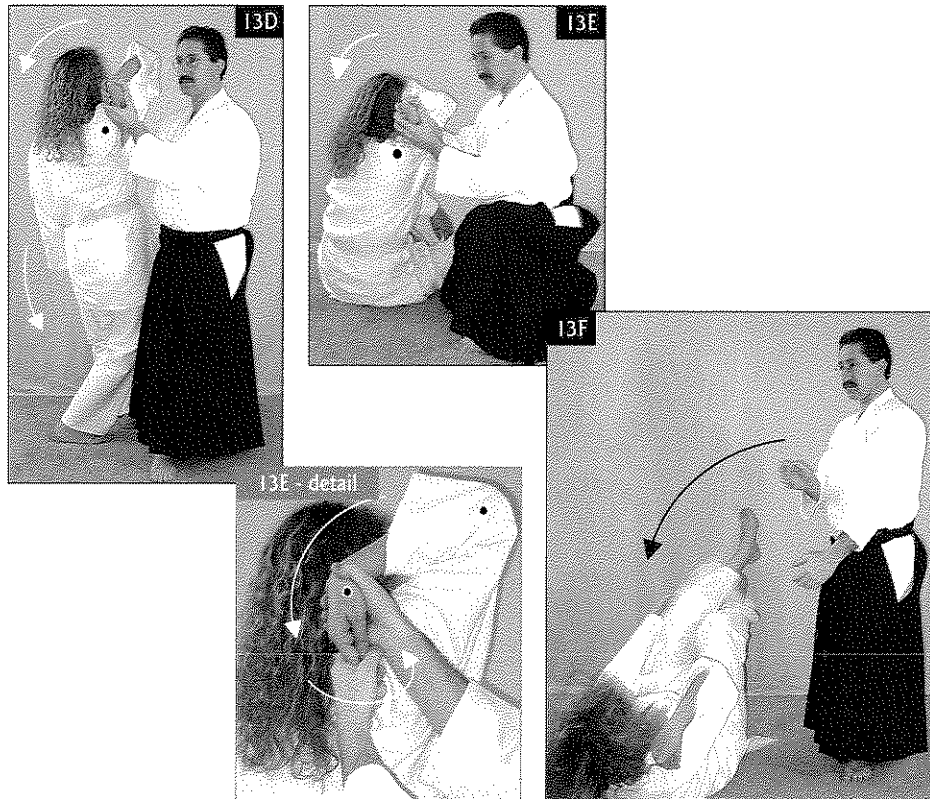


FIGURE 13 - Projections / Throws

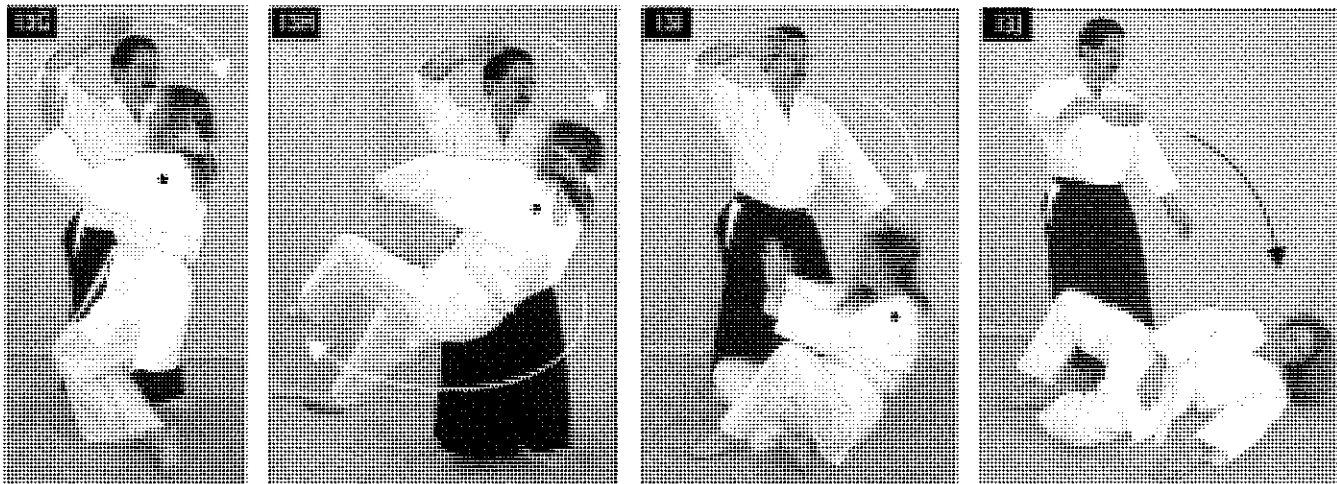
13-A-C Harpoon-throw. The aikidoist (standing) leads the attacker into a stooped position (A) before projecting her into a forward roll (B) and a break fall (C). The roll and break fall describe equiangular trajectories similar to those shown in Figures 11-A and B, respectively. White arrows show the main equiangular trajectory. Note how the joints (black dots) are aligned according to the progression of the spiral motion (A-B). Black arrows indicate the direction of the projection.



13-D-F Wrist-bent-toward-shoulder throw. The aikidoist (right) bends the attacker's wrist toward her shoulder (D), leading her to sit (E), or projecting her backward down onto the mat (F). The bent arm describes an equiangular spiral centered in the wrist (see detail). The effectiveness of this technique relies on the connection between the bent wrist, the shoulder and the one-point. When rolling backward (F), the attacker's entire body follows the equiangular trajectory initiated in the wrist.



13-G-J Breath-throw. The aikidoist (left) leads the attacker to pass in front of his chest area (G) while projecting the attacker back down onto the mat. In this powerful projection, the center of the main equiangular motion is located in the upper torso (black dot). The attacker's entire body pivots at this point (H). A backward roll (I) or a break fall (J) are possible outcomes of this technique.



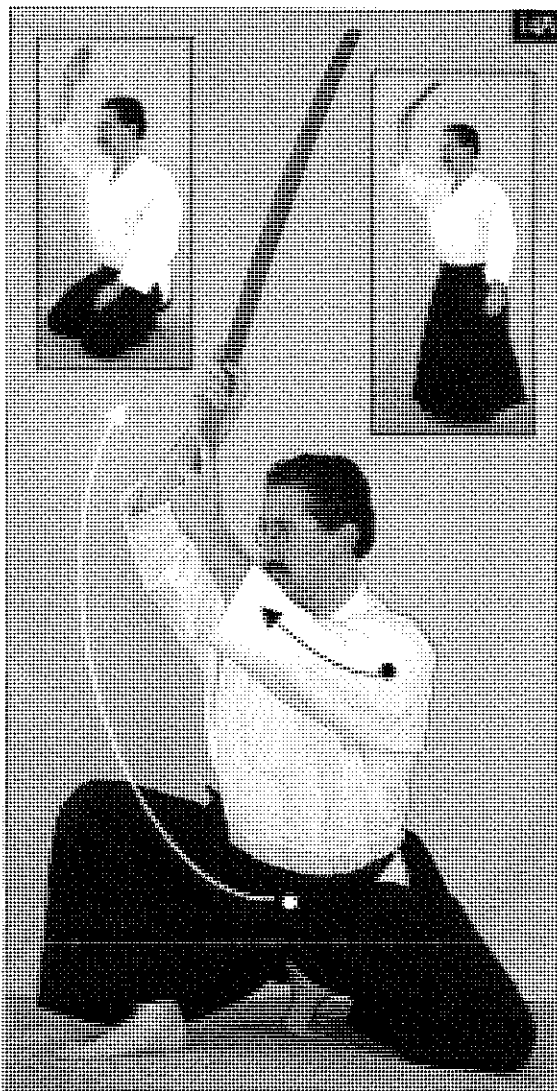
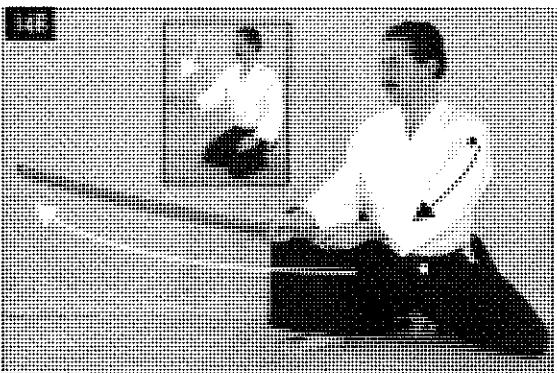


FIGURE 14 - Weapons

14-A *Bokken* (wooden sword).

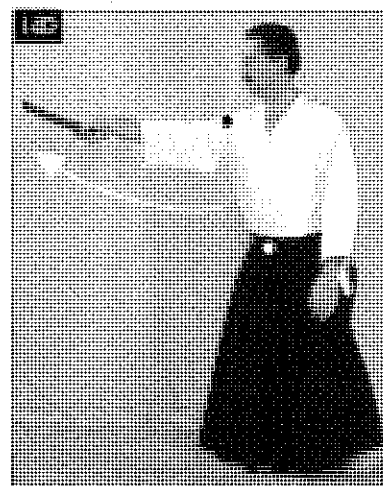
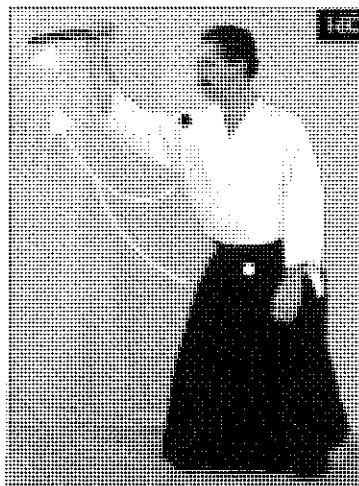
Upper-level readiness posture (tip of the bokken pointing to the sky). The aikidoist maintains an equiangular connection between the one-point and the weapon; secondary equiangular trajectories are also evident in the forelimbs. Similar connections should be maintained with a short-reach weapon, such as the wooden knife (*tanto*, right), or without a weapon (open hand, left).

14-B When a bokken-cut is performed, it should describe a wide-open equiangular trajectory centered in the one-point. Note how the same principle is applied with an open-hand cut (no weapon, left).



14-C Tanto poke. After completing an upward/forward arm swing (first equiangular motion), the aikidoist is ready to poke with the wooden knife (second equiangular motion).

14-D Thrust with the tanto illustrating a wide-open equiangular movement centered in the shoulder and connected to the one-point.

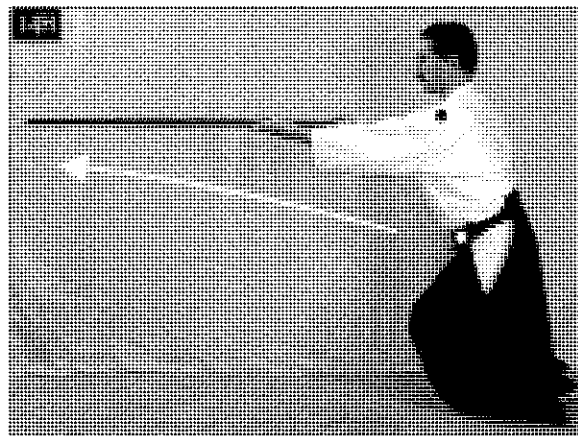
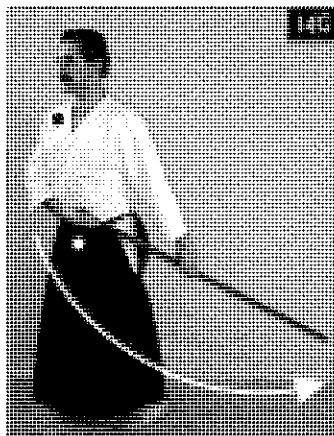
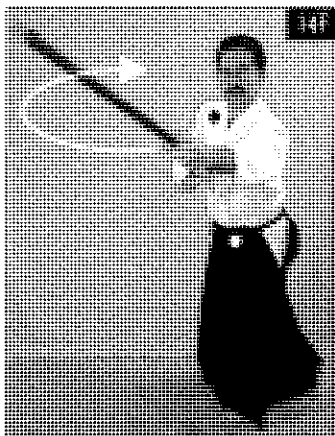
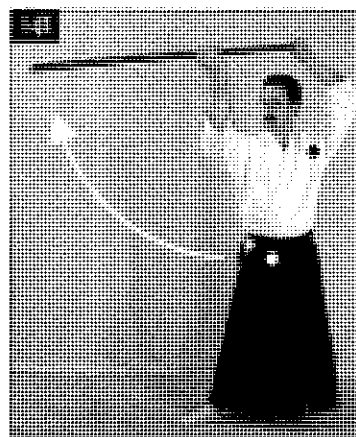


14-E Upper-level block/strike/poke with a *jo* (wooden staff). A wide-open equiangular motion centered in the shoulder and connected to the one-point is executed.

14-F Side/diagonal strike with the *jo*. The spiral motion is parallel to the mat and centered in the shoulder.

14-G Down/back block and/or backward poke with a *jo*; the spiral is clearly shown.

14-H Long and deep frontal thrust with the *jo*. Even though in this technique the aikidoist appears to perform a perfectly “straight-line” poke, the overall body motion describes an equiangular trajectory centered in the shoulder and connected to the one-point.



CONCLUDING REMARKS

The concept of the equiangular spiral is not restricted to aikido. Most martial arts, like judo and karate, or even swordsmanship (*kendo*) or archery (*kyudo*), include equiangular motions in their techniques, even though practitioners of these disciplines may not be aware of it. The human joints are designed, in conjunction, to follow spiral pathways that can be so wide-open that they appear to have strictly straight-line trajectories (i.e., a poke with a *jo* like the one shown in Figure 14-H) or so narrow and close that their spiral nature is difficult to detect (e.g., the twist of a finger). It is true that – as the inquisitive reader may well argue – some individual joints move in only two directions like, for example, the flexion and extension of the knee joint, which does not describe an equiangular trajectory. However, this joint can interact with others, like the femur-hipbone joint and the ankle joint, generating the equiangular trajectory followed by the entire leg in a front kick (Figure 10-1). It is because of aikido’s nature, with its evident swirling movements in throws, rolls and break falls, that it is perhaps appropriate to call aikido the art of harmonizing equiangular spirals. Nonetheless, numerous martial arts routines in other disciplines can also be explained according to the physics and dynamics of the equiangular spiral.



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ACKNOWLEDGMENTS

We dedicate this article to Mark Rubbert, William Reed, and Koichi Kashiwaya who have inspired us to explore the fascinating complexity of Shin Shin Toitsu Aikido (founder Koichi Tohei). Very special thanks to our mentor Mark Rubbert (Senior/Associate Instructor) and the St. Louis Ki-Society members for continuous support and friendship. The Ki-Aikido students at the Student Recreation and Fitness Center, The University of Memphis (TUM), motivated us to develop the ideas discussed in this article. Jane Orcholski, former Program Co-ordinator Campus Recreation Intra-mural Services, and Steve Whistler, current Recreation Services Coordinator, at TUM, helped us to initiate and continue with Ki-Aikido classes at TUM. We thank an anonymous reviewer for comments on the manuscript. The material discussed in this article is not necessarily endorsed by Ki-Society or any of its affiliates.