restoration, inhibition, and facilitation with those of physiology, psychology, and biomechanics.

The method, like the human body, has a skeletal structure around which the form is developed. The form comprises games/activities, group dynamics, music and movement, and so forth, which can be freely used, but a semblance of order is maintained by the skeletal structure. This structure, outlined in a 10-point program, is a guide to progression: unlike the 10 Commandments, it is a positive structure, stating, "Thou shalt DO" rather than "Thou shalt NOT."

The 10-point program is outlined in the four phases of human learning that are associated with physical movement. It is essential that the phases are considered in a specific order to avoid the common error that so often exists: teaching a complex swimming movement to a person whose mind is focused on one objective only—survival.

The time taken for each phase depends entirely on the degree and nature of the individual handicap. The 10 points can be defined briefly as follows:

1. Mental adjustment. An appreciation of the differences in the elements—land versus water; the comparison of posture and movement on land and in water; the realization that there are two effective forces in action, gravity and buoyancy.
2. Disengagement. The encouragement to use any newly developed ability without mental or physical assistance.
3. Vertical rotation control. The control of balance and movement around a transverse axis (sitting to lying).
4. Lateral rotation control. A control of balance and movement around a longitudinal axis (rolling from a prone to a supine position).
5. Combined rotation control. Control around a diagonal axis. This is usually essential for the more asymmetric body to control changes in its shape and/or posture.
6. Mental inversion. A psychological step involving an attempt to stay under water, opposing the effect of the buoyant force of the water. It is also an adequate response to the points previously taught.
7. Balance is stillness. The ability to maintain a posture in water against the disturbing forces.
8. Turbulent gliding. An expression that covers the activity of the body that is moved in the supine position through the water. The body is not touched and no propulsive movement is performed by the swimmer.
9. Simple progression. The body is now required to make a simple movement, establishing a progression through the water.
10. Basic movement. The application of a defined, larger-patterned movement of progression. It is based on hydrodynamic principles

Biomechanical Principles Applied to the Halliwick Method of Teaching Swimming to Physically Handicapped Individuals

K. Nicol, M. Schmidt-Hansberg, and J. McMillan

In 1949 James McMillan taught a group of severely handicapped girls, most of whom were afflicted with cerebral palsy, to swim. The method that was devised and developed was named after the institution where it was originally developed—Halliwick School in London. Support for this venture was received from an orthopaedic surgeon, Oliver J. Vaughan-Jackson, now a Visiting Professor at Newfoundland University. The method is now practiced in every continent of the world.

In the development of the teaching technique, consideration was given to the various needs and abilities of the handicapped so that they could control the movement of their asymmetrical body shapes and densities. In this regard, no two people are alike. The physical requirements cannot be dissociated from mental reaction that may result from a situation involving loss of balance.

By observing any child who is learning physical movement or an adult who is acquiring a new physical skill (e.g., ice skating), a noticeable pattern of human learning can be seen. It starts with a mental adjustment to the elements or environment of the activity. This is followed by efforts in gross patterns of movement, which can be referred to as balance restoration. Success in this phase leads to the prevention of movement while holding a starting position or posture—inhibition. Finally, a mentally pleasing and physically controlled movement—facilitation—is accomplished.

THE HALLIWICK METHOD

In the Halliwick method, a teaching program has been developed that allows individuals with various handicaps to be taught in one group. The method incorporates the principles of mental adjustment, balance

One year ago, the Halliwick method began to be used at Frankfurt University to teach the handicapped to swim. The swimming class consisted of seven physically handicapped children, aged 8 to 9 years, and an equal number of students who acted as teachers. Since it was desirable to have the teachers act in a specific way, according to the children's specific handicap, an instructional method based on the demonstration of the behavior of a model of the human body in the water was developed to illustrate the biomechanical principles involved in swimming instructions.

FACTORS AFFECTING BUOYANCY

Any object that has a density less than that of the water can float without movement, which means that a part of the body is always above the water. The ability of the human body to float depends on several factors:

1. The temperature of water (an increase of 1 °C lowers the density by 0.3%).
2. The content of salt in the water (1% salt increases the density by 2.3%).
3. The density of the swimmer as determined by the somatotype (it varies by approximately 10%).
4. The volume of air in the lungs (1 liter, corresponding to about 20% of the vital capacity, changes the body density by about 1.5%).

Usually therefore, in water of about 20°C, having a low salt content, the normal body type during normal inspiration can float in a vertical position. The immersed volume displaces sufficient water to support a position of the head out of the water, but the extent varies with body build. In most cases one is unable to breath in this position; therefore, the task is to look for a stable position that enables the individual to breathe and to survive in water.

For simplicity, let us examine the behavior of a rectangular cube of wood. As is the case with nearly all objects placed in water, this piece of wood has several stable floating positions, which indicates that it will return to its original position when it is displaced slightly and released. When the displacement exceeds a certain limit, the object will not return to its original position but will continue to move to a new position of stability. The more stable the position, the greater will be the force that is required for this transition.

To look for a stable breathing position for the vertically floating subject, lift his feet so that he is floating horizontally. The position should be supine with legs extended, the hands at the hips, and the face out of the water. In this position we hope that the subject can breathe comfortably and will be stable. The result of this experiment may vary. Some persons

can remain in the horizontal position with a certain degree of stability. Others will rotate around their longitudinal axis so that they retain the horizontal position but with their face down in the water. Most people will return to the vertical or near vertical position. The result is that the human body, when it is extended and the hands are at the hips, may have one, two, or even more stable positions in water. However, only one of these will enable the subject to breathe comfortably without movement of any kind.

BIOMECHANICAL PRINCIPLES APPLIED TO THE FLOATING BODY

It was necessary to develop procedures to put the body of all subjects into the desired position and to demonstrate these techniques to swimming teachers. Two different methods were utilized to accomplish this. First, a capacitance-type force platform was waterproofed (Nicol and Krüger, 1979) and placed on the floor of the pool under the floating body of subjects to demonstrate buoyancy or buoyant forces and the influence of changes in body shape on the supporting force that is required to keep the body afloat. Second, a wooden model of the human body was constructed. To create the variations of the overall body density, some of the wood was replaced by air and lead, respectively. These additions were made so that the various parts of the model were related to the mass and densities of the various segments of the human body.

First, let us analyze what can be done to assist the subjects who are unable to remain in a horizontal position. They move to a vertical position because the density of their legs is about 1.2, whereas the density of their trunk is about 0.8, generating an angular moment. There are three ways to compensate for this moment, as illustrated in Figure 1.

1. The moment is decreased when the lever arm is decreased; therefore, the legs are flexed.
2. The angular moment of the legs can be counteracted partly by another moment created by the arms (also having a density of 1.2) which are lifted over the head.
3. The counter moment of the arms can be increased if the hands or parts of them are raised above the water, thus reducing the buoyant force and increasing the apparent weight.

The second problem is to prevent rotation around the longitudinal axis of the subject. In such movements the moment of inertia is small compared with that of the transverse axis, so the body is in a state of critical equilibrium when it is displaced from the symmetrical position by more than 15°. Therefore, balance of the paraplegic (asymmetric about the pelvic axis) is much easier to maintain than that of the hemiplegic

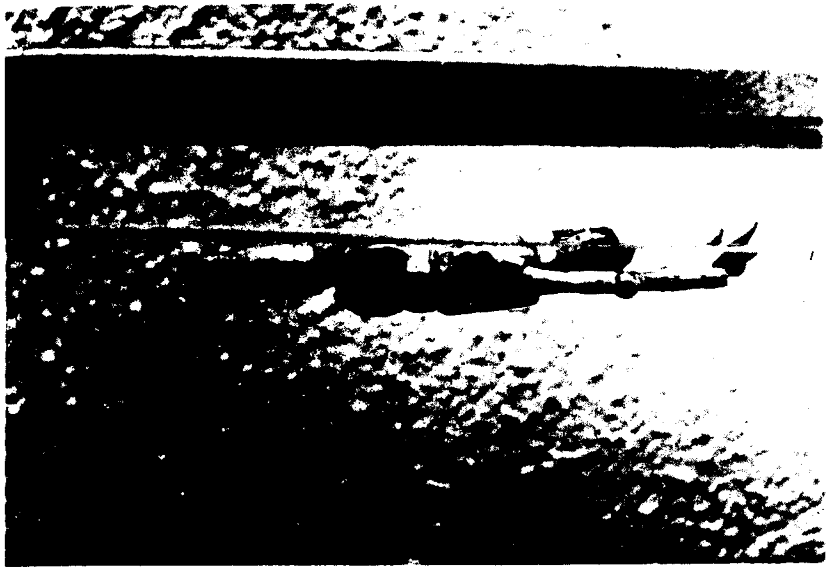

Figure 1. Standard swimming position.

(asymmetry around the spinal axis). Massive amputation or a similar abnormality in shape and/or density leads to a need for simultaneous control around both spinal and pelvic axes to maintain a controlled posture.

When rotation starts, parts of the body will move upward and may even come out of the water if their distance from the axis of rotation is great enough. In this case, the buoyant force on these parts becomes zero, and an additional force is generated. When this force is multiplied by the perpendicular distance from the axis, a restoring moment is generated that tends to stabilize the body. This stabilizing force can be increased greatly if the subject spreads his arms and/or legs and thus increases the distance and the stabilizing angular moment (see Figures 2 and 3).

The second way to prevent longitudinal rotation is to compensate for the asymmetry—e.g., by lateral flexion of the hip to the side that tends to move downward; by doing this, parts of the arms and legs that have a higher density are moved to the lighter side.

Another way to prevent rotation is to put the arm of the heavier side (say the left side) across the chest. In Figure 4, this is demonstrated for a hemiplegic. When this is done, the subject will rotate to the heavier side if he does not place his arm far enough to the right. Only when his elbow is placed near or across the center line will the angular moment caused by the asymmetry be counteracted. The reason for this is that parts of the arm come out of the water when it is placed across the chest, so the buoyant force on these parts is zero, and an additional angular moment is

Figure 2. Overcompensation of the moment around the pelvic axis in a one-sided amputation of the lower leg.

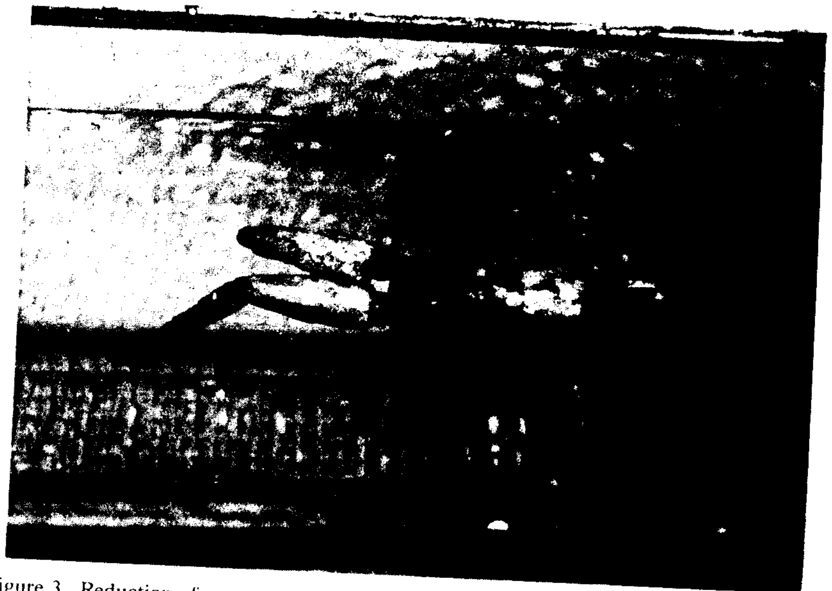

Figure 3. Reduction of overcompensation.

Figure 4. Compensation of hip flexion by the crossing of one arm over the chest.

generated. When the elbow is placed across the center line, the additional moment results in an overcompensation, thus balancing the moment caused by asymmetry. A similar result can be obtained if the subject crosses the leg of his heavier side over his other leg; by doing this, the result of asymmetry is compensated for, and the body is stabilized. This method can be used, for example, to stabilize the position of a single-leg amputee who tends to roll to the side of his remaining leg. When the forearm of the same side is crossed over the chest, that part of the forearm that comes out of the water stabilizes the body (Figures 5 and 6).

In this way, the swimmer can lie on his back and breathe safely. To increase his safety and to make him independent from the teacher, it is necessary to enable him to: 1) restore the supine position when he has come to a prone position by accident, 2) come to a standing position in shallow water, and 3) return to a swimming position.

Restoring the body to a supine position from the prone position is achieved by lifting an arm out of the water (preferably on the heavier side)

Figure 5. Rotation around both axes in a one-sided amputation of the thigh.

and crossing it over the back. An angular moment is generated (by the same mechanism as previously described), thus, turning the body onto the back.

Most people achieve the standing position simply. They need only to reverse the procedures that they followed to retain the horizontal position. When this is not successful, the hands should be brought to the sides at the hips, they should then be slightly out of the water, and they should be maintained in that position until a vertical attitude is achieved.

The final task—that of getting the subject into a swimming position without the help of the teacher—is achieved simply by the subject laying back into the water, placing his hands over his head, and flexing his knees, if necessary.

In this way, teachers were able to have these handicapped children restore their balance according to their individual needs. After 30 hr of instruction, five of seven children were able to stay in deep water without undue risk.

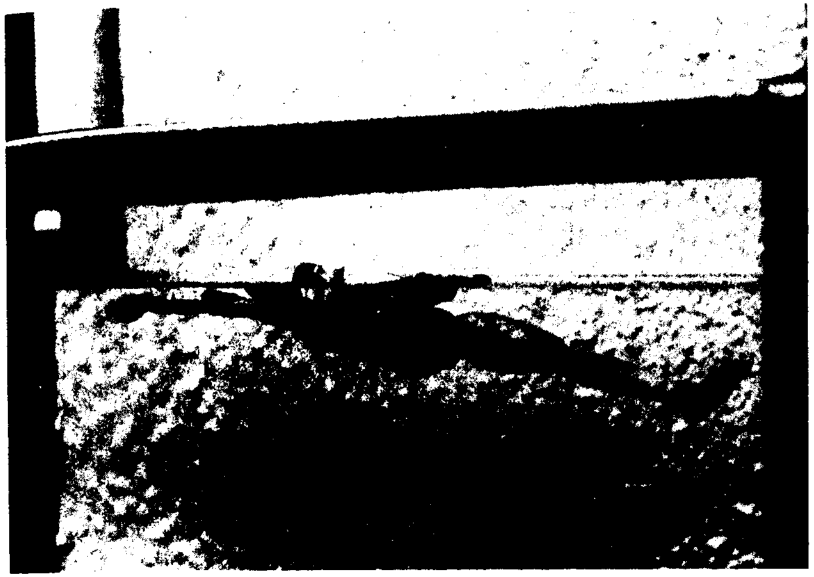

Figure 6. Compensation of both rotations.

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