SOME NOTES ON CANES AND CANE TIPS

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Many varieties of canes serve diverse purposes; therefore, a cane should be selected for the individual in the light of his special needs. For example, an orthopedic cane (1) or walking stick is quite different in characteristics from the exceptionally long cane or "Typhlocane" (2) used by the blind. The "white cane" laws of many states aim to protect blind persons in crossing streets. Stout walking sticks are used in many countries on rough cobblestone roadways, hilly or rugged terrain, to reduce fatigue on long walks, and perhaps as a defensive weapon. In former times, a dress cane had succeeded the dress sword as part of a gentleman's furnishings. Occasionally, a cane has combined functions, such as concealing a sword or an umbrella. At the New York World's Fair, an exhibit tracing the history of hearing aids included a speaking trumpet mounted as the handle of a walking stick. An orthopedic cane, however, is intended primarily to improve balance and to provide moderate support for a disabled individual.

These informal notes will be devoted to orthopedic canes, based chiefly on over thirty-five years of personal use because of polio, observation, and pondering over biomechanics. It is hoped, though, that a systematic evaluation of the necessary requirements, observation of other users, and discussions with some of them have modified personal prejudices of the author.

WHY USE CANES?

A cane can support considerable vertical load. It is not as effective as a crutch when support of a major part of body weight is essential, although one can balance with two canes for brief periods. Even a single cane broadens the base of support, increasing stability both on level ground and on an accelerating vehicle or a rolling ship.

A cane can greatly reduce muscular forces needed for balance as observed from front or rear. Biomechanical analyses by Pauwels (3), cited by Blount (4) and recently supported by experimental studies in Sweden, emphasize the great reduction in load upon the neck of the femur brought about by reduction of tension in abductor muscles through very modest support provided by a cane held in the opposite hand. Such a reduction may be essential for a patient with prosthetic hip replacement or a repaired fracture of the femoral neck. Even a small amount of support likewise may prevent grossly visible limping by a patient with weakened hip abductor muscles.

Similar biomechanical studies of Radcliffe (5) on the support of body weight of an above-knee amputee emphasize the need to tense the abductor muscles to stabilize the amputated femur within the socket. A cane carried on the opposite side, acting (like a push on a crowbar) at a long lever arm from the ischial support, can sustain a much larger force than that exerted on the cane, thereby dramatically reducing the horizontal counter-forces to be developed between stump and socket. These forces must provide a force couple balancing that generated on the pelvis by body weight acting downward through the center of gravity and supporting forces acting upward through the ischial support and other parts of the socket. This reduction in forces and hence in pressures may be especially desirable for a patient with a very short or abducted stump. (Carrying a briefcase, package, or handbag on the affected side has a similar action, but the reduced horizontal lever arm from hand to ischial support of the amputee or hip joint of the cases studied by Pauwels implies a lesser effect in reducing forces.)

In studies of the side view, the values of a cane in checking forward motion of the body directly after heel contact and transmission of force at push-off are not always recognized. Thus the arm and shoulder musculature, transmitting forces through the cane, can reduce demands on anterior tibial, quadriceps, and calf muscles. Reduced muscular effort in turn may reduce demands on impaired circulation, especially in the lower leg.

Reduced muscular forces resulting from use of one or two canes allow lower energy consumption per unit distance walked. (Also, relaxation of mutually antagonistic muscle groups associated with greater confidence and security may further reduce energy consumption.) Very informal tests by Dr. Henry J. Ralston of the University of California, using the present author as the subject, showed: (a) maximum energy consumption per meter walking unaided, (b) reduction with one cane, and (c) further reduction with two canes. Because of the greater security associated with canes, though, the self-paced "comfortable" speed increased successively. The composite effect was greatest energy consumption per minute with two canes, though least energy per meter.

The value of a cane in providing sensory feedback also may be overlooked. It allows body sway during standing to be detected at a considerable distance from the ankles; small corrective forces may then be applied at a substantial lever arm. The cane likewise detects irregularities of the walking surface. In darkness, for cases with weak vision or even bifocal glasses, and, of course, for the blind these sensory functions may be very important.

In comparison, crutches offer more support and stability, but canes are lighter, more easily stored when not in use (e.g., on public transportation, in automobiles, or in restaurants or offices), and cause less clothing damage. When medically feasible, the more convenient canes are preferable to crutches for providing supportive and sensory functions.

SELECTING A CANE

When canes are prescribed, the following are some factors for all concerned to keep in mind.

Length

The orthopedic cane is frequently too long. Shops customarily supply a 36-in. cane, a length suitable only for tall individuals. This stock cane should be cut down for most individuals. The cane should be long enough so that when the cane tip is on the ground close to the side of the body, as in Figure 1, the elbows are slightly flexed. An excessively long cane (Fig. 2) requires excessive flexion of the elbow, with correspondingly excessive demands upon the triceps muscle; inadequate support is almost inevitable. There is also an undue load upon the wrist due to ulnar deviation (Fig. 2), unless the whole hand is slipped around the crook of the cane, leading to an unsatisfactory position, lack of support, and need for unduly tight grasp of the cane handle to avoid slippage. An excessively long cane also leads to a tendency to elevate the shoulder, causing bad appearance and possibly scoliosis. Scoliosis is particularly marked in individuals who use only a single cane. The most common error observed among cane users on the street (and even in rehabilitation centers and hospitals) is the careless or unwitting use of excessively long canes.

On the contrary, a very short cane, resulting in substantially complete extension of the elbow, provides inadequate support after heel-contact and yields insufficient assistance at toe-off. A short cane particularly causes difficulty in lifting the body during climbing of stairs without excessive hip flexion and forward tilting of the torso. Excessively short orthopedic canes are so inconvenient that they are uncommon.

Handle

A decorative handle has often been used on dress canes. A gold ball, for example, may be adequate for casual swinging, but it is not suitable for an orthopedic cane intended for appreciable support.

The handle of the orthopedic cane conventionally is curved (Fig. 3). This crook should be large enough to fit comfortably over the forearm even when the user is wearing an overcoat so that he may hang the cane temporarily on his forearm while using his hand in making change, grasping a handle on a bus, etc. The crook should be slightly more than 180 deg. so as to afford a good grip on the forearm even when inclined so its center of gravity is under the forearm, yet the crook should not continue so far as to prevent the cane from slipping readily over the forearm plus an over-

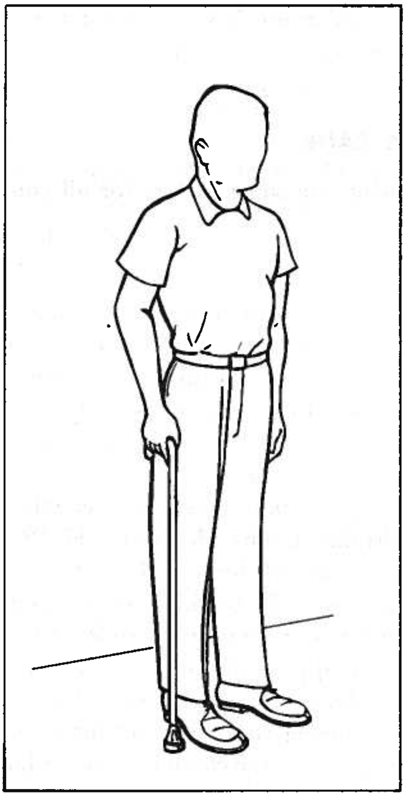

FIGURE 1. Cane of proper length for individual subject. Note slightly flexed elbow, firm "pistol grip" on handle, and forearm almost in straight line with shaft of cane.

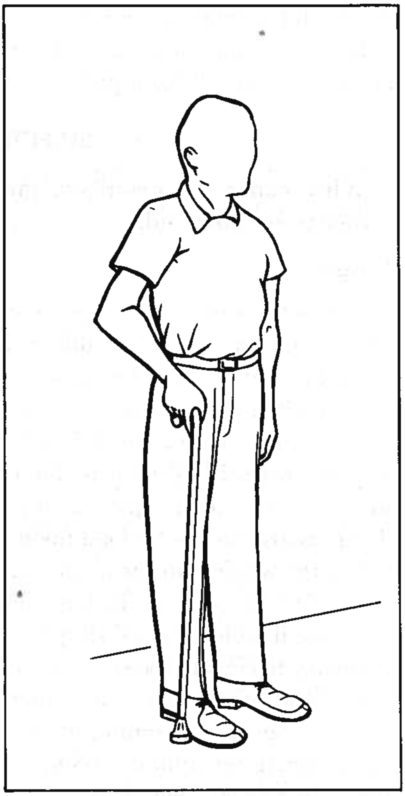

FIGURE 2. Cane that is too long causes elbow to flex excessively, shoulder to rise slightly, and hand to move to awkward position.

coat sleeve. (An extension of the crook like a sword guard, to encircle the hand holding the cane, was formerly sometimes recommended in a cane for the blind so as to protect the knuckles from bumping against hot pipes or sharp edges. This feature is deliberately omitted in the current Veterans Administration specifications. It seems undesirable in an orthopedic cane.) The cane should remain securely on the forearm even if it swings in pendulum fashion during forearm movement. Preferably, the cane should also remain at rest when hooked over hand rails or when the lower edge of the crook is placed upon the top of a desk, counter, etc. A dome-like end is preferable to a sharp bevel. (Small inserts or coverings of rubber or similar materials of high coefficient of friction in contact with common surfaces may be applied to the lower end of the crook in order to hold the cane more securely upon the glass top of a counter or showcase.)

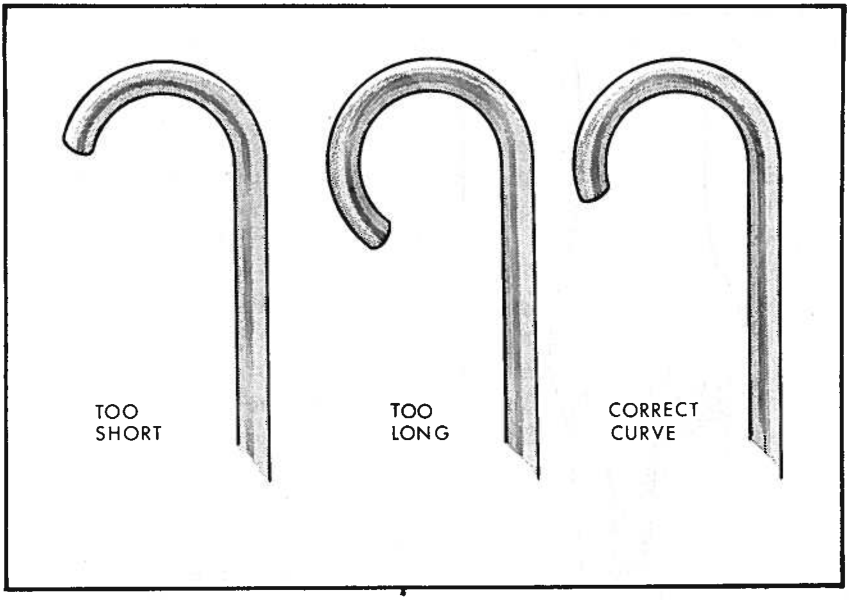

FIGURE 3. Correct curve of cane handle is slightly more than 180 deg.

The material in the crook should be sufficiently large in diameter to permit the hand of the individual user to attain a comfortable "pistol-grip" type of grasp (Fig. 4), with the curvature of the crook fitting into the arched palm. Many canes intended for orthopedic use, and almost all canes for dress purposes, are too small in diameter to afford a satisfactory grip for the average male adult, leading to contact between the finger tips and the palm of the hand and to needlessly tiring continuous muscle activity in an attempt to grip the handle securely. An extremely large cane handle, however, such as that of a man's cane offered to a child, also would give an insecure grip because of lack of satisfactory encircling of the cane handle.

The ring, middle, and small fingers should encircle the middle part of the crook, and the thumb and index finger should guide the cane, with the index finger extended down the shaft. Preferably, the distal phalanx may be bent somewhat as on a pistol trigger. Any knots or similar projections on the cane material should aid this pistol grip. Callouses forming on the user's hand may assist stability of grip.

An integral handle formed from the main cane shaft with due care to avoid stress concentration seems generally preferable. The material should be bent carefully to preserve its round cross section. Carelessly bent handles are unduly flattened into oval sections.

A separate handle may be preferred in some cases, especially with dress canes, but the attachment region is likely to be a source of weakness. (How-

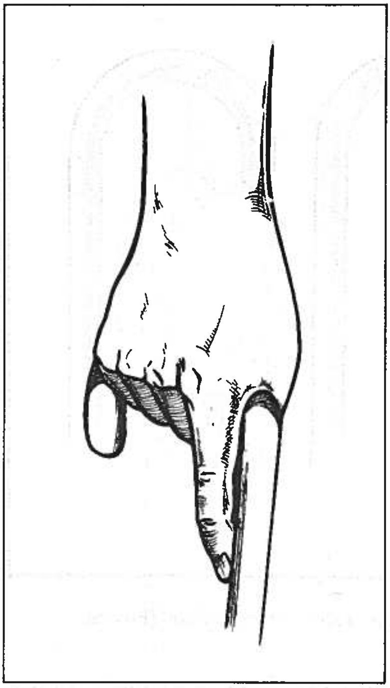

Figure 4. "Pistol grip" with hand placed forward of curve of handle for firm and secure grasp. Distal end of extended finger is curved around the shaft slightly for ease in accelerating and guiding the cane.

ever, careful design and modern materials may allow strong and durable joints suitable for orthopedic canes.)

T-shaped handles are often used to transmit the loading forces more directly down the shaft. This type of handle can be shaped to fit neatly in the hand, but it is often a stock item with a hammer-like shape, somewhat convex upward to fit into an average palm and projecting forward of the cane shaft to allow gripping by the thumb and index finger.

Stiffness

The diameter of the cane and the material from which the shaft is constructed should be such as to give adequate stiffness even when under at least half of body weight. Normal loads upon the canes used by the writer seldom exceed 20 lb. each, as measured during walking over a gymnasium platform scale. More accurate measurement of transient forces by means of a force plate or of strain gages on a special aluminum tubular cane remain to be made. During climbing stairs, however, the loads on the cane will typically be much greater. When necessary, the individual should be able to balance momentarily upon his two canes, setting up the requirement of support of half of body weight. Presumably there is also an impact factor which will still further increase axial loading. Because of the application of the load at some leverage, approaching half the diameter of the crook or handle, there will also be considerable bending load upon the cane. The cane, therefore, should provide adequate stiffness under all customary loadings without appreciable deflection. Many malacca and similar light canes intended primarily for dress purposes are appreciably flexible under even a small portion of body weight, resulting in at least some feeling of insecurity for the patient as well as in decreased sensory feedback.

Flexibility under load typically increases the lever arm at which body weight is applied, thereby increasing bending moment, compounding the deflection once started, and raising the stresses in the outermost fiber of the material, thus increasing the risk of breakage. It should be remembered that in determining stiffness as a beam or as a column, particularly under eccentric loading, the properties of a cross section through the cane are more important than the actual cross sectional area. The effects of distribution of material on both strength and stiffness are exemplified by the properties of a bamboo shaft contrasted to a thin rod of equal cross section.

The diameter should permit snug attachment of an adequate rubber tip at the bottom. As we have seen, the diameter of the handle must allow a comfortable and firm grip.

Occasionally, a spring-loaded cane (or crutch) is advocated to provide shock absorption by telescoping against spring resistance when load is applied. Such a concept seems unwise. During the swing phase, the unloaded device is needlessly elongated, so it must be circumducted or the elbow and wrist must be flexed excessively.

Weight, Density, and Other Physical Properties

In most cases, the actual weight of a cane is relatively minor since it is swung in a pendulum fashion from the shoulder and with limited motion at the elbow and the wrist. (The center of gravity should be high and the moment of inertia about the cane handle should be small, though, to permit rapid walking without conscious use of muscles controlling the wrist.) In other cases, however, it is convenient to have a relatively light cane. A substantial and attractive wooden orthopedic cane is available at low cost from a number of well-known department stores and artificial limb and brace facilities, which weighs approximately 1 lb.

All too often, however, one finds both dress canes and wooden "hospital" canes which are needlessly heavy, even though small in diameter, because of the particular grade of wood which has been used. Such canes not only are burdensome because of weight but offer a needlessly insecure grip because of the small size of the handle and the very slippery varnished finish which is customarily supplied. Since such canes are frequently used for temporary disabilities, there may be inadequate attention to the length of the cane. Furthermore, the handle usually curves much too sharply to fit comfortably over the forearm. These "hospital" canes are often made by bending a dowel turned from a larger piece which does not precisely follow the grain. Thus, they seem more likely to crack along the grain deviations than a cane bent from a single rod or branch which happens naturally to be of the proper diameter and thus retains its natural surface. The turned dowel also lacks the natural projections which, when selected for the individual hand, assist in obtaining a "pistol grip."

Some dress canes are of exceptionally dense wood, such as ebony, which provides a needlessly heavy cane of unsatisfactorily small diameter of handle. Almost all dress canes are very small in circumference and hence provide inadequate grip for adult males.

Occasionally, it is desirable that a cane with its cane tip be capable of floating in water. The author, for example, is accustomed when entering the water for swimming, to walking along the sloping bottom of the lake on which his family has a camp. At some point between knee and hip immersion, the canes are tossed ashore, placed on a pier, or allowed to float in the water while the swimmer simply tumbles into the water. Later, the canes are readily retrieved in water of about knee depth. Assisted by the buoyancy of the water as well as by the canes, the swimmer climbs to his feet so that he can wade ashore with the aid of the canes. This technique would not be necessary if one were swimming from a pier equipped with a ladder extending into deep water (provided one could climb the ladder). The ability of the cane to float is desirable, in any event, when one uses a small boat or canoe or in cases of emergencies. (The typical hollow tubular metal cane is not sealed, so it would not float.) Most wooden canes would be satisfactory in this respect if the cane tips were not excessively dense.

There seems relatively little need for aluminum tubular canes from the consideration of weight since many of these are actually heavier than available wooden canes. In addition, aluminum may present other problems, such as conductivity of electricity and the tendency to conduct extreme temperatures (either hot or cold).

Finish

Perhaps needless to say, canes should not split, absorb moisture appreciably, or decay. An attractive, washable, and durable finish should be provided.

Aluminum canes should have an anodized or Alumilited finish which would prevent smudging of hands or clothing and add resistance to "scuffing" and scratching. In addition, Alumilite can be produced in attractive colors which if desired could make the cane more visible to others, as a safety feature in traffic, as well as more attractive. Consideration might also be given to a coating of sintered nylon or polyvinyl chloride powder, a technique used recently for aluminum braces in Europe.

THE RIGHT CANE TIP

Based both on the writer's experience and on careful engineering analysis, rubber cane tips are essential. Plain wooden ends or ferrules of metal or horn are inadequate to resist slipping or to bridge small openings.

Design

Cane tips should have concentric rubber rings on the bottom surface, with the outermost ring preferably projecting slightly beyond the next inner ring (Fig. 5a). The lower portion of the cane tip should be relatively flexible so that the rings come in contact with the ground uniformly even though the cane is inclined at a slight angle from the vertical, as in projecting to the side from the body in any event or ahead and behind the body during normal walking. This flexibility, plus the design of the rings, permits firm contact with the ground during the entire walking cycle. Limited torsional flexibility also is desirable.

The sides of the cane tip should flare gently (Fig. 5b). Sometimes it is necessary to hold a door open with the cane and cane tip, then withdraw. The flaring or cylindrical portion allows these actions without catching. Some tips, designed for greater flexibility, have a projecting thin disk at the bottom held by a narrow rubber post. The projecting disk may catch under a door (or even in underbrush).

In an effort to extend the wear period, the cane tip preferably should have a metal reinforcing disk buried in the material below the end of the cane shaft (Fig. 5c). This reinforcement avoids punching through the cane tip under pressure from the cane shaft and assures the desired distribution of load to all parts of the concentric rings.

Skid Resistance

If the ground is slightly wet and smooth (one of the conditions likely to cause skidding), the concentric rings (Figs. 5a, 5c) exert a suction cup effect. This is particularly noticeable with a fresh cane tip before appreciable wear has occurred. In addition, the slim, sharp-edged, and flexible rubber rings have a squeegee action tending to push away a film of moisture, slime of dead leaves, or similar extremely hazardous lubricant, and thus to "bite through" to relatively dry surface.

It may be noted that one of the most hazardous conditions for walking with crutches or canes arises from the presence of dead and decayed leaves on a wet sidewalk in the autumn. (Smooth slate sidewalks in old residential sections seem to be particularly hazardous.) Another very dangerous situation is created by a film of water on top of a smooth surface of ice, as during the morning of a winter day when water melted the previous day has frozen overnight in a smooth surface, but a small quantity has remelted to form a lubricant. Property owners can reduce these hazards materially by adequate maintenance.

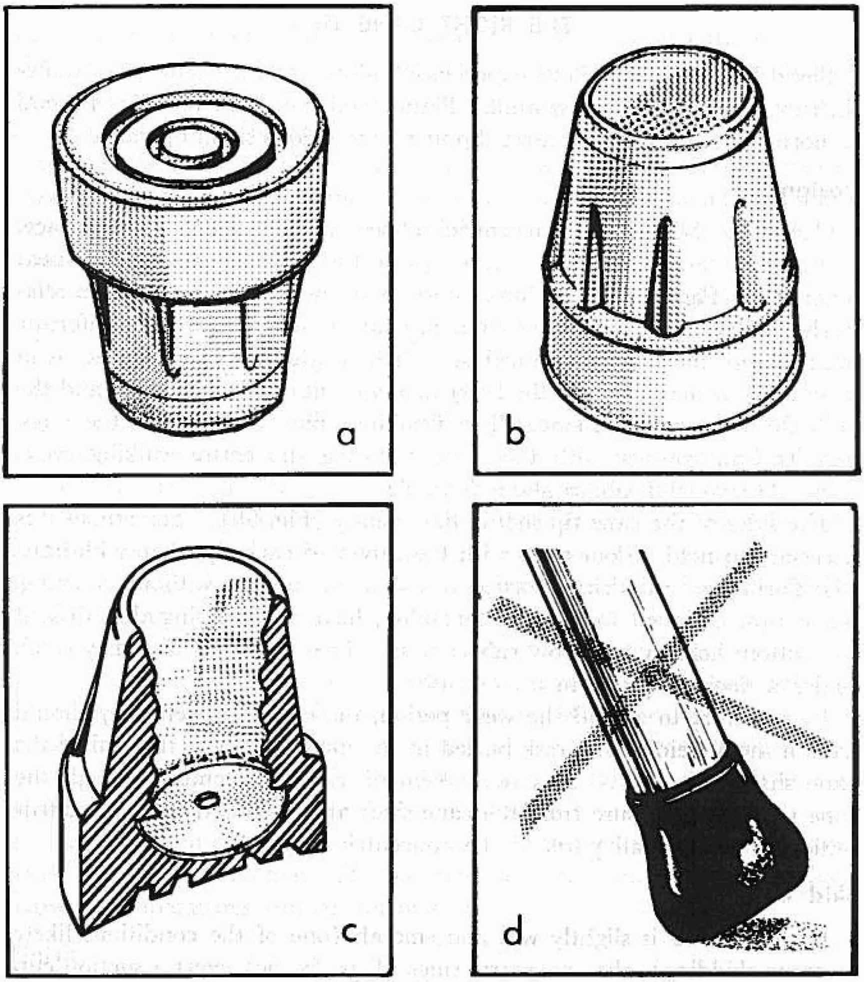

FIGURE 5. (a) Rubber cane tip with somewhat flexible concentric rings for suction cup effect, (b) slightly flared tip to aid in such actions as holding a door open, (c) cross section depicting metal reinforcing disk used to distribute pressure on concentric rings and to prevent end of cane shaft from punching through rubber, (d) inexpensive, rounded tip of hard black rubber, considered hazardous.

An unexpected slippery spot, encountered at normal walking speed, is particularly dangerous. One may surmise that a person continually computes a little-understood trade-off function between estimated hazard, cost of undue delay, energy expenditure, and perhaps other factors.

On slippery surfaces the user attempts to walk with the canes as nearly vertical as possible and with the load applied substantially vertically (requiring short steps), and to minimize all forces in the horizontal plane, both by reducing fore and aft accelerations and shearing forces during walking and by preventing substantial rotation of the pelvis during walking. If one can control twisting of the lower extremities about the longitudinal axes by voluntary use of muscles, torsional shearing forces can also be minimized at heel-contact and toe-off. Unfortunately, the conditions requiring use of canes often include paralysis of the muscles normally controlling relative rotations of the lower extremities, pelvis, and shoulder girdle as well as those controlling shearing forces.

Size

The rubber cane tip should be large enough in diameter to bridge most small irregularities found in the normal pathway. In large cities, the cane tip should fit across the space between bars of subway gratings, fire escapes, or sidewalk ventilators. Unfortunately, certain holes in manhole covers are just slightly larger than a practicable cane tip, so the user must be careful to avoid placing the cane directly on such holes. A reasonably small cane tip, in contrast, is desirable in walking on rough ground, frozen snow and slush, or ice because the small tip permits entrapment in small valleys or irregularities or at least careful placement of the tip in local areas which seem to offer the best coefficient of friction, thus giving maximum available protection against slippage. It is frequently possible to place a reasonable size cane tip in a pocket left by the freezing of snow or slush deformed by the heel of an overshoe, thereby obtaining security even though the ground as a whole is quite slippery. Similarly, it is sometimes possible to pick out areas which have been made rougher by passage of automobile tires or to select patches which have been sanded voluntarily or by wind-blown dust and cinders.

A relatively large cane tip is desirable during wading to avoid sinking into clay or mud in the bottom of the lake. The cane tip, gripping the shaft of the cane fairly firmly, must not be pulled accidentally from the cane by sticking in clay. The tip should be nearly cylindrical, without a barb-like projection to stick in the mud if it does penetrate.

The tip should not grip the shaft so extremely firmly that the rubber encircling the cane shaft is unduly stretched and subjected to accelerated oxidation and deterioration because of the high stress. Correctly selected tips endure at least three months and often a year or more of active walking before the rings wear nearly flush with the body. Earlier replacement is a wise precaution.

Unfortunately, metal prongs or sharp points (so often suggested to prevent slipping) have appeared to be unsatisfactory. They become dulled upon bare sidewalks, which is frequently encountered under the climatic conditions causing the serious hazards, and they may fail to penetrate the ice unless the user delivers a dangerously forceful impact upon the cane. They must be removed or retracted before entering a building. In contrast, it appears desirable to use rubber cane tips.

Perhaps the most hazardous cane tip is the small inverted hemisphere of hard black rubber which is ordinarily found on inexpensive canes (Fig. 5d). Its only conceivable virtue is its low initial retail cost, perhaps half that for more satisfactory cane tips. The hemisphere, however, is extremely dangerous because the V-shaped wedge of lubricating film between the tip and a damp sidewalk fulfills the laws for perfect lubrication of bearings. The tip glides on the film like a water ski, leading to slipping. Similar tips with a few small concentric circles are scarcely better since these small circles are so stiff as to give little, if any, squeegee action, and, in any event, they are rapidly worn away.

SUMMARY

The proper cane and cane tip give the user considerable security in walking and other activities and permit much more rapid walking even if anterior tibial and calf muscles are missing or weakened or if lateral balancing muscle groups are weakened. The cane length should require only moderate elbow flexion. The handle should permit a comfortable pistol grip. The weight need not exceed a pound, with the center of gravity high. A flexible rubber tip with several concentric rings should conform to the ground and should give a suction-cup action on wet surfaces. An inadequate cane, usually chosen from carelessness rather than from logical economy, can be extremely hazardous.

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