Biomechanics And The Understanding Of

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The American Teaching System (ATS) has been carefully developed over the years by drawing on many areas: learning/teaching theory and practice, sports psychology, group management concepts, equipment technology and biomechanics. It is generally accepted that the skills concept is central to the ATS Skiing Model and that our understanding and interpretation of ski technique is based on the definitions of the basic skills.

A Short Review Of The Skills Concept

Our current understanding of skills differs somewhat from the early descriptions in that all are now movement focused and the concept of control is integrated into the skills definitions. Thus we understand the fundamental skills to involve:

**Balancing Movements:** The movements required to keep the body in equilibrium (either static or dynamic) when acted upon by external forces. These external forces may be the result of deliberate actions by the skier (turning the skis, adjusting edge angles, etc.) or they may result from reaction to disturbances (uneven snow surfaces, terrain, etc.). The balancing movements may involve relatively gross adjustments or almost imperceptible adjustments, as dictated by the circumstances.

**Rotary Movements:** movements that can be characterized as involving rotation, or tendency toward rotation, of either the body as a whole or one part of the body relative to another. As is the case with balancing movements, the rotary movements may be subtle or quite strong, may be fully developed or blocked (tendency toward rotation), active or reactive, depending on the situation and the skier's wishes.

**Edge Control Movements:** movements of the body resulting in an adjustment of how the edges of the skis interact with the snow surface. The concept of “control” is introduced to the edging movements to clearly recognize that the forces which ultimately turn the skis come from the ski-snow interaction in one form or another, and that the edges are the active interface between the skier and the snow.

**Pressure Control Movements:** movements that are used to regulate and adjust the pressure experienced by the skis as they move on or through the snow.

There has been a tendency in to “short-cut” terminology when using skills concepts. This has been particularly true with “rotary movements,” where the instructor drops any reference to “movement” and just states, “we need to add more rotary” or, “most rotary originates” or, “...rotary from the hips...” “Rotary” is an adjective and hence cannot stand alone - let’s be careful and not spread grammatically incorrect jargon!

The fundamental skills concepts need to be elaborated and related directly to events and actions in the context of turns, and this must be done for all levels of skiing development, from the introductory to the advanced levels. Whenever possible, description of desired actions must be specific and related to muscular movements that the student can understand. In this fashion, the fundamental skills are integrated into a focused method of analyzing skier actions and form the basis for specific instructions to the skier. Because the skills are now related to movements, they cover a broader area than before. As one can see from such discussion, an underlying set of values about the skiing experience is implied.

The Skiing Model Concept And The Center Line

The realization that a value system underlies specific application of the skills concept to skiing requires one to articulate a particular value system for “good skiing.” From an application point of view, the desired value system should be expressed through a “skiing model.” This is a difficult task, since beauty is in the eye of the beholder. Thus, one might expect the individualized personalized views of what good skiing is would preclude the establishment of a suitable value system (skiing model) that would serve as a practical basis for ski teaching and the implementation of the skills concept.

We do not believe this to be true; we believe that good skiing has a characteristic signature that allows us to define a useful skiing model and that this characteristic signature is independent of the discipline. *The characteristic signature of good skiing shows rhythm, flow of movement, efficiency, power, sensitivity and precision, and these qualities serve as the departure point for definition of a skiing model.* To be a universally
valid model, it must be applicable to all levels of skiing, from beginner to expert, in all conditions, from groomed cruising slopes to extreme skiing to racing, and to all age groups, from children to “senior citizens,” and it must be independent of the specific implement(s) of choice, i.e., alpine skis, telemark skis, or a snowboard. We believe that the qualities we have identified - rhythm, flow of movement, efficiency, power, sensitivity and precision - apply to all the variations we encounter in skiing. Even unsophisticated observers, who may have little or no knowledge of the sport, have little difficulty in identifying skiers who exhibit these qualities in their skiing, so this characterization appears to be quite sound.

To anchor the technical/mechanical foundations of ATS, we need to define the “skiing model.” What then are the components of a skiing model? First, one must describe its qualities and we have done that. Next, the fundamental building blocks must be identified. These building blocks are the fundamental skills identified above. Then, one needs to give a prescription of how one is to use the building blocks when applying the model and this requires a unifying structure. Finally, guidance must be provided for the application of the fundamentals so as to allow both the student and the teacher to clearly see the interrelationship of various tasks and exercises used to improve the student’s skiing.

To help focus the skiing model (provide the structure), which in turn serves to establish a value system, the concept of the skiing Center Line has been introduced in ATS. The Center Line is to serve as a reference with respect to which one can judge particular phases of skiing. A reference helps both instructors and students judge the level of achievement at any stage of student skiing development. Identification and definition of specific maneuvers representative of the progression from elementary skiing to high levels of proficiency provides the reference (structure) we seek, and this set of basic maneuvers defines the Center Line. The selected maneuvers must be consistent in the manner in which they showcase the fundamental skiing skills, form a logical progression from simple to complex movements, and the image they convey must reflect the characteristic signature of good skiing, i.e., display rhythm, flow of movements, efficiency, power, sensitivity and precision. The specific maneuvers selected to define the Center Line then serve as “check points” during the suggested instructional progression.

From the intended purpose of the Center Line, we see that it is not the content of lessons to the customer. We do not “teach the Center Line”. Customers do not come to lessons with the personal goal of learning a specific Center Line maneuver. What we should be teaching customers are movements and movement patterns that will provide them with success in whatever skiing situation they may find themselves.

Thus, we need to provide specific guidelines to how the fundamental skills are applied at each level of development, as measured by the identified maneuvers of the Center Line. These guidelines should identify the common features of each skill that can be observed at each level of the Center Line as defined by the selected maneuvers. This requirement leads to the following guidelines:

**Balancing Movements.** Balancing Movements are more efficient and effective if: There exists a functional relationship of the legs. A fairly tall stance is encouraged to allow for better muscular and skeletal efficiency. The balancing actions involve the whole foot (neither toe nor heel bias) as well as both feet; this develops the ability to work the entire ski. The upper body is disciplined and has a dynamic relationship to the skis. Turns are linked with a continuous flow of the center of mass to produce and maintain rhythm. At the turn initiation, the center of mass moves toward the new turn, releasing the edge and enhancing rotary movements. During turn initiation the skis are actively guided through muscular actions, thus greatly enhancing the flow of the turn.

**Rotary Movements.** Rotary movements are more effective and efficient if: The rotary movements of the legs enhance the actions of each other. The rotary movements are used to support an active guidance of the skis throughout the turn. The rotary movements are used to complement pressuring and edging movements.

**Edge Control Movements.** The edge control movements are more effective and efficient if: The edge control movements start from the center of mass, with fine tuning adjustments made with the ankles, knees, and upper body. The skis are guided onto the edges and subsequent edge adjustments are used to assist in achieving the desired turn shape.

**Pressure Control Movements.** Pressure control movements are more effective and efficient if: As the turn develops, the shift of pressure to the inside edge(s) is smooth and progressive. Flexion-extension, fore-aft, and lateral movements complement other actions in the control of turn shape (action with, and reaction to, terrain variations contribute to these movements).
These guidelines are intended to help the instructor focus lessons on specific goals and to help him or her quantify student desired outcomes. Because the guidelines apply in a consistent manner to all maneuvers, considerable freedom exists in the choice of appropriate tactics. The instructor is faced with a large array of choices during the course of a lesson, influenced by such factors as student progress or changing conditions.

**Biomechanics, The Skiing Model & Skills**

As we review the skills definitions and the guidelines for the application of the skills concepts to skier development, we see that the key concepts are all biomechanical: We talk of movements, control of movements, the characterization of the movements, the effect of differing movements, and the shaping of the movements as we progress in the skills levels from beginning to expert skiers. Thus a deeper understanding of the skills concepts, and the skiing model we wish to use as a reference, requires us to look at the biomechanics involved.

Traditionally, when instructors think of “biomechanics,” the reaction has been: “Oh no, not that incomprehensible, esoteric stuff of vectors, forces, Newton’s laws, and who knows what else! Why can’t we just keep it simple and talk about ski technique instead...” Yet discussions of ski technique are often based on some interpretation of what the underlying mechanics are and what is going on with the body, skis, etc. even if the term “biomechanics” isn’t used. Not only is this true with discussions of technique, but is even more evident in clinics on “movement analysis” or “error recognition/error correction.” So perhaps we do need to think a little about what biomechanics is and how the concepts may help us in our discussions of technique, movements analysis, etc.

First, let us define what we mean by “biomechanics.” The term itself is a composite and relatively recent addition to the English language meaning the study of living creatures in motion; in particular, humans in motion. In the “70’s and early “80’s, biomechanics was primarily involved with measurements and some limited modeling to predict human motor variables that cannot be measured directly. In the “90’s; the focus has shifted to issues of motor control of human movement. The goal of the study of biomechanics and motor control of human movement is to assess and understand human movement, a goal that is becoming more realizable as a result of progress in our understanding of the basic physics involved, advances in modern computing technology, measurement and measurement processing technology, and our understanding of how muscles work.

Certainly one approach to “biomechanics in skiing” is to base all analysis on the traditional approach in engineering and physics. That is, start with the identification of all the forces acting on the skier/skis, draw appropriate diagrams which display how and when these forces act on the skier/skis, and then analyze the situation after deciding what motion we wish to study. The problem becomes quite complicated, since to apply the basic laws of Newtonian physics, one is faced with the difficulties of identifying the appropriate reference frames. Furthermore, the forces involved are all continuously changing in time and the body-generated forces may originate from different muscular actions, many of which still produce the same overall effect. The situation rapidly becomes quite confusing even for individuals trained in the analysis of dynamic systems. The usual temptation is to assume some simplified models or to identify what one believes to be a key characteristic of the situation and then to build the analysis based on these assumptions. This approach is sometimes successful, sometimes merely confirms something that one knows from experience or, more often, leads to erroneous conclusions.

An alternative approach suggests itself when we realize that the primary help we need from biomechanics is guiding our thinking about the effectiveness and efficiency of movements for selected tasks. After all, if one intends to make a turn in some direction, does something with the body and the skis and the change in direction takes place, then there is nothing “wrong” with the movements. What we are concerned about are the qualities of the movements involved: were they as effective as they could have been, as efficient, did they “feel good,” did they “look good,” or whatever other criteria we might wish to apply. The characteristics of good skiing we have identified all focus on the qualities of the turns and movements, not on whether a turn actually happened or not. Granted, that is the first concern of the student: “Can I make the turn where and when I want to?” Once that happens, however, the purpose of instruction is to shape the qualities of the turns and extend the range of conditions under which the student can use the turns they know how to make. The quality of motion in fact is what we are judging when we look at someone skiing, whether in a certification setting, teaching situation, or just casual observation on the slope.
To give ourselves a firm foundation when judging quality of movements, we need to consider questions of efficiency and effectiveness. First, let’s consider the issue of efficiency: efficiency is clearly related to the expenditure of energy to accomplish a given task. So this tells us that we should consider the mechanics of movements from the point of view of energy expenditure, a much easier concept to deal with than detailed analysis of forces and moments and so on. In addition, we can readily observe whether movements are efficient or not: smooth, flowing movements are easily identified. Body language signals clearly whether someone is “working hard” or not. Even without the blessing of biomechanics, everyone has an intuitive feeling that jerky, harsh movements with visible tensions are not efficient. In the ATS skiing model we capture this idea in the descriptions of what makes a movement efficient by using terms such as “flowing,” “smooth,” “guiding,” “enhance,” “continuous flow,” and so on.

This view is supported by the current thoughts in biomechanical research. A decade ago, very little was being done regarding the energetics of human movement. Now, the focus is on the “human motors” themselves as generators, absorbers, and transferors of energy. The sources of energy that need to be managed in the context of skiing are the energy we derive from gravity (given to us by the price of the ticket which partially pays for the electrical energy to raise us in the gravitational field via lifts!), the energy available in our bodies (metabolism), and the energy available in the equipment as the result of deformation of the materials. So we can judge the quality of motion by how we manage the energy available to us to accomplish the goals we set for ourselves in skiing, whether these are minimum time from one point to another in a racing setting, or maximum enjoyment from a full day of skiing the mountain. Recreational skiing, as any other motion sport, is enjoyable because of the sensations of speed and control of motion; and smooth, seemingly effortless movements give most satisfaction.

What then are causes of inefficient movements? The most obvious is when extensors and flexors work in opposition (contraction). The muscles are essentially fighting themselves to produce some net movement, resulting in a high expenditure of energy. This type of activity occurs most often when the individual feels the need for stabilization of the body while performing some movement. We feel this as tension during the run, exhibited in different body segments. To feel how this enters your own skiing, focus on how much relaxation you can achieve between turns or what muscles are working during a particular turn. Note the difference as you move from groomed “Syber snow” to garbage to bumps or whatever.

Another cause of inefficiency is isometric contraction against the force of gravity. In ATS, this source is addressed directly by the discussions on stance and how the center of mass should move during turns. The preferred mechanism of reacting to gravity, as well as other forces that arise during skiing, is to use skeletal alignment and not muscles. A somewhat more subtle point is that anytime you hold a limb in a stationary position during motion you are more than likely doing work against the force of gravity in addition to whatever else is going on.

A cause of inefficiency closely related to contraction is when energy is generated at one joint and absorbed at another. This is a bit difficult to visualize, but often happens during alternating limb movements. For example, in normal walking, this occurs during the double support phase when the energy increase of the push-off leg takes place at the same time that the weight-accepting leg absorbs energy. It is obvious that this type of activity needs to happen - the basic mechanics of biped walking task require such movements - however, the efficiency of the event is determined by just how the movement is executed; i.e., one should not expend any more energy than is absolutely necessary for the task.

The last major cause of inefficiency in movement is the relative smoothness or jerkiness of the movements. Smooth movement is characterized by continuous interchanges of limb energy. In jerky movements we have a succession of stops and starts, and each of these bursts of energy generation and absorption has a metabolic cost. Jerky movements are inefficient.

Another area where we can gain some insight on energy consideration, without getting all tangled up in the perils of detailed mechanical analysis, is in the analysis of turns, specifically the efficiency of turns. We spend a lot of time discussing turn shape and how different movements influence turn shape. The real issue is to first decide what the purpose of the turn or series of turns is to be and then we can see what is pertinent to the discussion. Simply put, the primary purpose of any turn is to change the direction of travel of the skier down the mountain. To satisfy this purpose, any movement that results in the desired change of direction is correct. However, we usually hang other requirements - qualities - on the turn, and these can radically
change the mechanics involved. If we focus on the efficiency of turns, then we cover everything from racing to recreational skiing.

Efficiency is an energy management game: If you want to be the fastest down the race course, you need to be careful of how and where the energy is lost. For the recreational skier the same considerations hold, even though maintaining speed may not be the primary goal as it is for the racer. In the ATS skiing model we focus on the concept of continuous flow of movement, a concept that is directly tied to where in the turns you scrub speed, and what the results are from the movement of your center of mass. If the changes are not smooth, then it is likely your body reactions will not be smooth either. And as we have remarked, jerky movements are inefficient.

As the above discussion indicates, we can gain considerable insight into the mechanics of skiing from thinking about energy without getting too involved with the details of mechanics. However, for some purposes, we do need to think about forces in detail and how those forces originated and are applied. For example, when analyzing the sequence of movements that take place when we perform a given turn, we need to consider how movements are initiated and what happens thereafter. A complete understanding of biomechanics does require an understanding of basic physics and anatomy.