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SKI TEACHING WITH HEALTHY FUNCTIONAL BASE

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ABSTRACT
According to various interpretations the objective is to learn to ski, nonetheless within controlled boundaries. The thematic route acts as a guideline for the ski instructor, to show what comes after each stage, how to proceed. In this system, the assessment of the harmful or healing impact of exercises on health remain hidden in the background.
Introducing somebody into a sport is not simply learning some movements. Learning a new movement, building a skill always based on existing knowledge and known skills. The fundamental natural movement patterns have the deepest imprints and the greatest influence on motor learning [1][2][3]. The nervous system never will learn something from scratch, it always will look for something known skill or pattern to construct a new one [4].
According to the kinetic chain theory [5], the constraints on the whole system can be described by the constraints on the connected elements. The kinematic chain is the sequence of these connected elements [6][7]. To understand the behaviour of the system it is necessary to analyse the movement and constraints of the connected elements.

KEYWORDS*: Kinetic chain, motor learning, healthy movement, skiing*

INTRODUCTION

Introducing somebody into a sport is not simply learning some movements. Besides motor learning, it is the set-up of new habits, skills, forming the relationship to the environment, rebuilding self-confidence, learning the rules, etc. The motor learning section of this process is a huge scope itself. It is not only the learning of a new independent motion, rather learning of a complex set of motor skills. Each new movement and skill connected to other ones [4]:
Learning a new movement, building a skill always based on existing knowledge and known skills. The fundamental natural movement patterns have the deepest imprints and the greatest influence on motor learning. The nervous system never will learn something from scratch, it always will look for something known skill or pattern to construct a new one.
A new form of movement appeared, and experts had to re-evaluate their existing knowledge. We can be of the belief that sport movements are traditionally determined, they are axioms. Around the world several thematics and technical and methodological mind-sets exist relating to skiing. Skiing as a sport is developing rapidly, we need to learn and analyse our work continuously to be more effective. 20-40 years ago there were no talks about the importance of core muscles, unstable exercise tools were not widely used, running drills had no significant role in ball games, output quality was not a major aspect of conditional training. In fact in most places these principles are still not applied to this day.

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The ski instruction thematic can only be understood when viewed in conjunction with its objectives. These objectives may include the learning of a specific type of turning, they may relate to aesthetics (teaching a certain style of skiing), or they may be an exact goal (such as teaching how to ski faster) etc.

Background: musculoskeletal system, motor control, movement patterns

The mechanical structure of the motor system

According to the kinetic chain theory [5], the constraints on the whole system can be described by the constraints on the connected elements. The kinematic chain is the sequence of these connected elements [7]. To understand the behaviour of the system it is necessary to analyse the movement and constraints of the connected elements. On the other hand, in a complex machine (i.e. human skeletal system) does not make sense to analyse only the operation pairs of segments and ignoring the connected pairs or the whole system. In other words, in a complex system, every part should be analysed considering the other parts [6].
The active part of the human motor system is the muscular system in complex with the fascias and tendons (*myofascial structure*). Otherwise, the myofascial tissues also have a connective mechanical role, in this sense, they belong to the passive system, too. It makes the whole system more complex because they overlap more than two elements (bones, joints), so they exert the effect of the movement of one element not only on the directly paired element but on other - not directly connected - ones (e.g. fascia lata) [1].

Control of the musculoskeletal system

The active part of the musculoskeletal system driven by neurological commands. To exert a specific movement a complex structure of muscles should be activated via neurological commands.

- Some of those movements are unique (a creative way to solve the situation).
- Another part of this set of movements is used often to solve typical situations.

Nevertheless, the musculoskeletal system has infinite freedom of movements, but there are typical patterns too. Those learned complex patterns are effective in certain typical situations. The most frequently used situations and movements generate the deepest imprint in the nervous system (standing, sitting, walking, running, jumping, etc. - e.g. the human natural movements). The personal motor repository consists of these habitual patterns [2].
In case of dynamic movements, the phasic muscles will not fulfil their stabilizing role in the mid-phase of the movement (after accelerating the body part at the higher speed). It is worth considering in the earlier phases of the learning process the use of slower movement to build up the skill of the stabilizing functions [3].
The human neuromusculoskeletal (human motoric system) is based on mechanical foundations and controlled by the neurological system.

- The contraction of one muscle exerts an effect at least two mechanical parts of the system.
- In vivo never happens an isolated contraction of one muscle. Every single movement is the result of the coordinative work of several muscles. ("In gait, muscles with similar biomechanical function tend to activate in synchrony

and distinct muscle synergies have been identified related to functional sub-tasks of the gait cycle (e.g., heel strike, swing).")[4]

- Those effects are combined in complex situations.
- Normal real-life movements require the harmonic movements of multiple bones and muscles.

When a muscle contracts, it exert force not only on the insertion but on the origin too. That's why the functional anatomy can describe the function of a muscle by a condition of a fixed origin.

E.g. m. rectus femoris extend the knee when the pelvis and the femur are fixed. When the femur is not fixed it flexes the hip. When the pelvis not fixed it tilts the pelvis forward. Ergo the *rectus femoris* can exert several effects depending on the activity of other muscles (or external forces):

- Knee extension
- Hip flexion - femur lifting
- Hip flexion - anterior pelvic tilt.

Anatomy can describe the functions isolated, but in real life, muscle activity is always complex. In this complex scenario, every muscle play own role:

- agonist (main activity), synergist
- fixator
- neutralizer
- antagonist

Some of these functions are naturally coordinated, some of them should be learned. The neuromuscular system is looking for the most effective variations for certain situations and not always considering a wider aspect (e.g. a whole turn or more turns in the skiing).

Some examples:

- A muscle reacts on a stretching effect with contraction because of the myotatic reflex. To exert an eccentric muscle activity needs a learned control level from the nervous system. I.e. when an increased load comes from the ground (sole) the extensors of the lower limb (plantar flexors, quadriceps, gluteus) reacting with higher tension, and the antagonist (dorsiflexors, hamstrings, hip flexors) getting relaxed. But in certain situations (i.e. in skiing) can a better answer not to increase the tension i.e. in the plantar flexors.
- When the main goal of a movement is in focus, the control not considering other goals. I.e. in the eccentric phase of a squat the nervous system send relaxing command to the quadriceps and the gluteus but not send tension command to hamstrings and the hip flexors because the gravity does the job. The gluteus as an extensor of the hip joint not only moving the femur but the pelvis too. Relaxing the gluteus can affect anterior pelvic tilt at the same time. Operating the eccentric phase of the squat with muscle tension of the hamstrings can protect the knee and preserve the good angle of the pelvis or the COM but not effective ergonomically.
- The reciprocal innervation [8] relax the antagonist muscle when the agonists are contracting. I.e. :

[4] https://onlinelibrary.wiley.com/doi/pdf/10.1002/jor.23391

- When the quadriceps are in tension (because the requirement of holding the body weight), the nervous system sends a relaxing command to the hamstrings.
- When the gastrocnemius engaged, the dorsiflexors will be relaxed.

Using the antagonists are effective in certain circumstances and protective for the joints. The reciprocal innervation can be overdriven on the higher level of the nervous system, which is a learned mechanism.

Overview of kinetic chain theories

A series of experts found some logic in the behavior of motoric system because of the structure above. In 1955 dr. Arthur Steindler adapted the kinetic chain concept from mechanical engineering [9] to the human movements (as an open and closed chain). Later the kinetic chain concept becomes more popular [10]:
The foundation of the chain models is coming from clinical praxis for the treatment of musculoskeletal disorders, not from sports. Most of the chain models exist for postural corrections because shortenings lead postural patterns (Françoise Mézières: kinetic chains is used to stretch all the muscles contained in a group at the same time).

- Straight chains (anterior, posterior) - more static, stance-related
- Crossed - more dynamic than static, gait
- Spiral
- Lateral
- Diagonal pattern [11].

Kinematics focusing on the factors which describe the system (position, angles, speed, acceleration). Kinetics takes in the account the causes of the motion too (forces, torques, etc.). In the case of a living environment to the causes belongs to the chemical-biological system (maximum power of muscles, fatigue, etc.), the motor control (nervous system), moreover in a broader sense the psychological factors too (fear, confidence, spatial orientation, feed-forward, and feedback postural balance control etc.) [12].
For example, on the bike, the leg of the biker and the bicycle builds a four-bar linkage (figure 1).

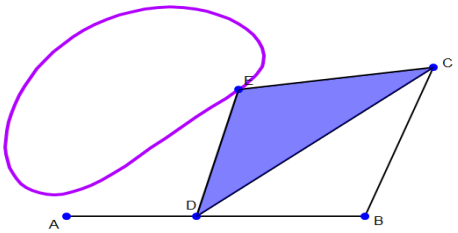

Figure 1: Bicycle movement

● Looking at the movement only it is not important which muscles are working. The form of the motion will be the same.
● In real life, on the bike, the rider can use multiple motor activities to achieve the movement:

- The hip and knee extensors and plantar flexors pushing down the crank. Only one active quarter.

- The same, plus with hip and knee flexors and dorsiflexors pulling up on the other side. Two active quarter.
- The same, plus pushing forward on the top phase (hip flexors, knee extensors, fixed ankle), and pulling backward on the bottom phase (hip extensors, hamstrings, dorsiflexors).

Another example is a skier. A deeper or higher stance is practically the structure of a squat. Squat is typically a closed chain exercise. Normally the extensors are active in a squat. It is not needed to use dorsiflexors because the gravity is enough to get a lower position. The movement meets the definition of "considerable external resistance that prohibits free movement". It is true by on the horizontal ground, but on the slope, the ski can accelerate. The result of the acceleration of the ski is the back position of the skier. Higher muscle tension in the dorsiflexors and in the hamstrings can pull back the ski (relatively moving forward the skier over the ski) and prevent the too aft position.

Coordinated chains

All motor function operates with a neuromuscular background [13], but the dynamic chains are more motor control related. In this case beside the mechanical connection, the sequence and the timing of the muscular activity is important too.

Stance

On the functional base, the antigravity muscles counterbalancing (stabilizing) the body against gravity. The mechanical structure of the skeletal system not stable itself. It can be stable only when it is stacked in one line in the centre of gravity [14]. The skeletal system will collapse without the stabilizing activity of the muscular system in the following areas:

- Ankle dorsiflexion: shin rotates anteriorly.
- Knee flexion: femur rotates posteriorly
- Hip flexion: anterior pelvic tilt
- Spine lumbar curve: increasing anterior
- Spine thoracic curve: increasing posterior
- Spine cervical curve: increasing anterior
- Head: protraction

The neuromuscular system tries to stabilize the skeletal system against collapsing.

This function is based on the stretch reflex (myotatic) reflex. The antigravity muscles extending the hip, the knee end resulting plantar flexion in the ankle (i.e. extending the leg).

The gluteus extends the hip and at the same time holds the physiological ankle of the pelvis. The abs muscles stabilizing the lumbar curvature, the thoracic muscles (i.e. rhomboid muscles) the thoracic curvature.

Not all parts of the body are of equal importance. Because of the posture, one of the most critical parts is the pelvis. The pelvis tends to tilt anteriorly following the collapsing mechanics of the skeletal system (one of the common central posture problems is the APT). That's why one of the most important muscle activity is the stabilization of the pelvis near to the physiological position. In this case, the gluteus and the hamstrings working in harmony with the abdominal area, on the other hand, the hip flexors with the lower back muscles.

This coordinative antigravity chain (or extensor chain) is a sagittal cross chain.

Squat

The squat is laterally symmetrical movement. In the starting position, the antigravity chain (or extensor chain) operates in the same way. The activity of the flexors is completely unneces-

sary for the main objective of the movement. On the other hand, the flexors can effectively protect and stabilize the joints (especially the knee), as well as control the fore-aft balance (especially with the flex angle of the ankle).
The squat has the following phases:

- Stance
- Lowering (eccentric) phase
- Bottom position
- Lifting (concentric) phase

The hip as a ball-and-socket joint allows a wide range of motion. Because of the femoral offset, the lower limb physiological tends to a valgus position. In the squat, during the flex, the lateral rotators and the feet position according to the sagittal plane can stabilize the leg against a valgus stance. So the lateral rotators are not main actors in the squat but take part in the coordinated chain as stabilizers.
Skiing is a special case. Normally the easiest way to avoid a valgus stance is starting the squat in a wider stance, feet rotated laterally. In skiing the normal stance is

- hip-wide and feet are parallel or
- shoulder-wide and feet are rotated medially (wedge).

Both stances have a higher risk for a valgus position. In those cases especially important the higher level of stabilizing work of the rotators.

a. Lowering phase

The lowering phase is an eccentric movement. According to the dynamic character can be different:

- When the movement is slower, there is no significant acceleration, and the muscle tone breaks the lowering of the body nearly linear from the start until the bottom point.
- When the movement is fast:
    - In the first stage, the body accelerates, there is no break effect, the antigravity muscles getting almost relaxed.
    - In the second stage is a deceleration, and the antigravity muscles have to break the body with a higher eccentric tension.

The lower limb extensors (antigravity muscles) release the muscle tension to allow flexing the hip, the knee, and the ankle.
The biggest challenge in the lowering phase of the squat is the decreased tension of gluteus, especially in the case of the fast movement. Gluteus is one of the most important parts of the antigravity chain. Decreasing the muscle tone of the gluteus increasing the risk of APT during the lowering phase of the squat. The other result of the low level of tension of the gluteus is the unstable femur (knee) because of the missing lateral rotating function of the gluteus maximus.
It is an important task to keep on the harmonic muscle tone in the pelvic area during the lowering phase of the squat, especially in the gluteus.

b. Bottom position

The bottom position principally similar to the stance from the aspect of muscle activity. The difference is in the joint angles.
Important that the joint angles influence the effective power of the muscles. The fiber of the muscles can deliver the best performance near their physiological length (Figure 2). Around 135° knee angle, all the muscles can exert effective force. In a deeper squat, the quadriceps

and the gluteus are stretched and the hamstring shortened, so they can exert a lower level of effective power (active and passive insufficiency).

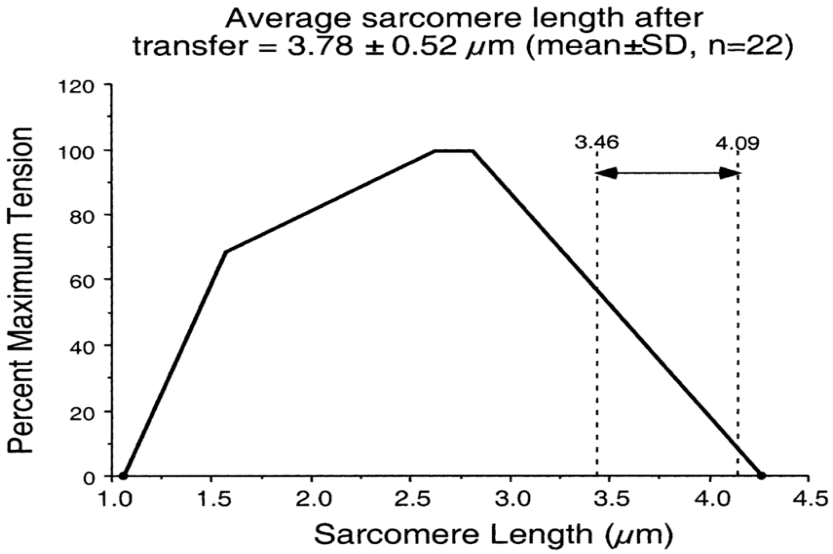

Figure 2. Average sarcomere length [15]

Approaching the very low positions there is a high risk of PPT because of the overstretched glutes and hamstrings. After it, in the lifting phase, the pelvis can swing and tilt too much anteriorly.

c. Lifting phase

The lifting phase is characterized by the concentric muscle activity of the extensors. When the extensors not working harmonically (less gluteus, more quadriceps) the stabilizing effect will less and cause valgus position. In this phase is essential the stabilizing work of the hip rotators.

Walking, running

The kinetic chains of walking are very complex, but it worth to analyze it, at least simplified, because walking has one of the deepest imprints in the nervous system. Sub-tasks of walking as patterns are in use in many other movements forms.

In the analysis of walking or running, we can consider some important phases of the gait cycle. Usually, in the analysis, one gait cycle begins with the initial contact (IC) to and last until the next IC. It is advantageous in the case of the posture analysis (aspects of kinematics) but in the case of the analysis of the dynamic muscle activity (kinetic scope) more perspicuous to begin the cycle with the toe off (TO) point.

During the IC, the body suffers a high impact what can resist only with a higher level of complex muscle work. This muscular activity should begin earlier (anticipation), so to take the IC as a first point means that we will step into the middle of a story. The swing phase is the preparation for the initial contact and for the absorption, so in the sequence, the swing phase is the first following by the stance phase. In reverse order, the internal logic is cannot be interpreted. On the other hand, during the stance phase, the other leg (which is in in the swing phase) has important objectives: stabilization of the pelvis and the lumbar area against the ground forces from the stance leg.

Unfortunately, in these researches only the lower limb included. An important task can be to replace it with wider research including the trunk too. On the other hand, there is a common problem with all of the researches of the human movements: they measure only one or some

person's individual technique. To get valid, generalizable results it needed to analyse a wider, valid population with an exact description of the measured movement. This is also true for skiing analysis too.

Gait chain

In the gait cycle, the function of the aerial (swing) phase is:

- Pelvic and lumbar spine stabilization.
- Preparation the optimal joint angles for the stance (anticipation).

The rule of thumb in the sport movements that a joint or the body *should be stabilized before the load*. In the gait cycle, the highest load is the impact. The biggest coordinative challenge of the gait is the anticipative preparation for the impact in the swing phase. Crucial is the sequence and the timing of the muscular activity to get ready for the initial contact with a backward pulling movement.

One possible sequence of the gait chain muscular activity (figure 3).

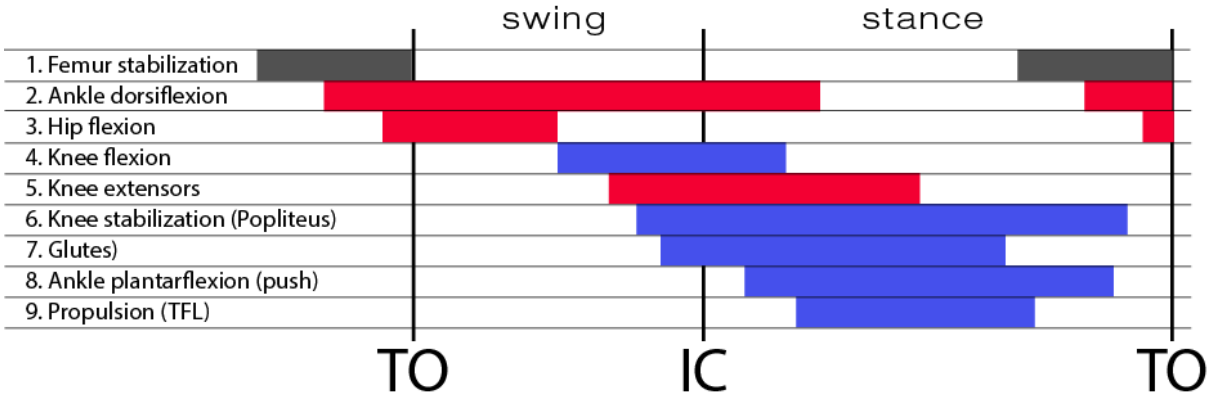

Figure 3. Gait chain muscular activity

There are some aspects we have to consider:

- Although the sequence starts with the hip rotator muscles, we can assume that the *trigger of the process is the dorsiflexion* (2). In details, it starts with the *lifting of toes.* A big advantage of this movement that it is easier to learn consciously as engage the hip rotators or the tibialis anterior.
- The dorsiflexion keeps on until after the impact, so it is a permanent part of the whole preparation process.
- It is a small detail, but important: the popliteus activity to stabilize the knee during (and shortly before) the stance phase.

Specialized sports movement and generic personal motoric patterns

All the specialized movements are based on the motoric patterns of the fundamental natural human movements. Every sport uses its own basic stances. To understand and teach these stances we have to use kinetic chains of the fundamental human stances and movements.

Even in the sport which not use directly such movement forms as walking and running are asymmetrical postures and loads. In these cases, the nervous system will transfer similar programs from the fundamental natural movements as proven successful solutions for the stabilization of the posture.

During teaching movements, the best way is to go from the easy to complicate, from typical to special, from natural to specific (figure 4).

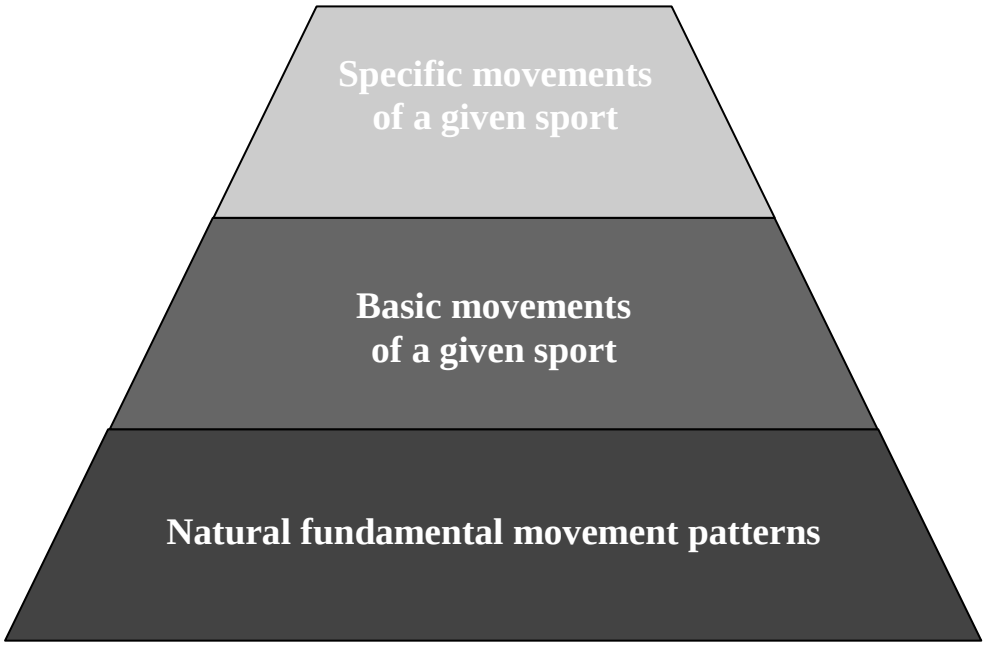

Figure 4. Teaching structure

In this manner, one of the best practices to teach the basic repository of a specific sport is based on the natural fundamental movement patterns. The basic movements of a specific sport are the connective network between the natural human movements and the specialized movements of the given sport.
Of course, the fundamental natural movements are not ready-to-use motor patterns. Sub-task and skill of this complex movement build the block of the personal motor repository.

Skiing and personal motor patterns

Basic motoric repository in skiing

The fundamental motor patterns are the reactions to the situations according to the relationship of the body and properties of the environment (like the acting external forces and spatial movement of the body).

Special skiing aspects

The basic stance and straight gliding are symmetrical two-leg postures, the conditions of these motions are dynamically constant.
When the trajectory of the skier differs from the fall line the posture is related to the one-leg support stance.
In the turn, the extent and the direction of the acting forces permanently changing. The reactions of the body can be based on the gait.
The wedge turn is a good temporary tool to:

- Transferring the postural patterns in the skiing environment.
- Getting to know the basic spatial characters and trajectories of the turn on the slope.
- Separations of the two legs and improve the gait chain skills according to the dynamics of the turn.

Specialties of the turn (figure 5):

- The dominant acting forces come from the turn.
- The outside leg carries the load, so this is similar to the stance leg's supporting function. The inside leg's function is similar to the swing function of the gait cycle.
- The transition is the preparation phase. The legs are changing their functions (stance-swing) during the transition.
- The inside leg works based on the swing phase of the gait. The IC point of the gait is in the 1. phase of the turn, where the ski is getting on the edge and the load builds up.
- From this point, the outside leg carries the load according to the gait pattern after the IC.
- In the 3. phase of the turn, the load is decreasing, the stance function of the outside leg is not necessary anymore. This is similar to the TO point, the stance leg function transforming to the swing.

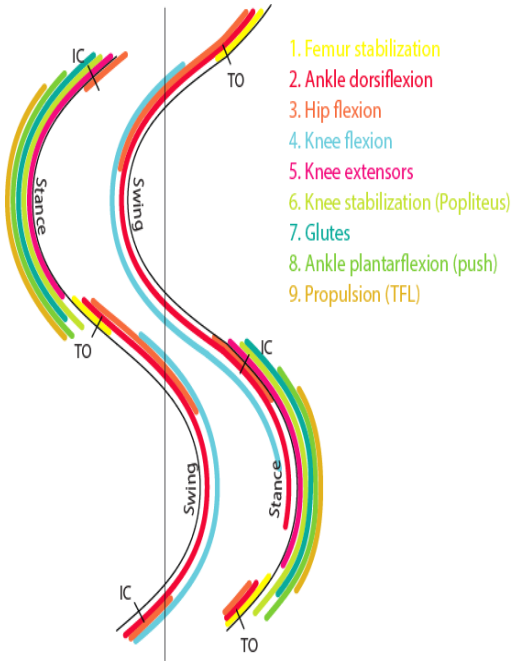

Figure 5. Turn phases and muscle activities

The basic skiing postural habits can be learned based on the natural movement patterns, but not all. Especially the spatial orientation can be strange for beginners. The logical postural habits are looking for the stability, e.g. this habits in the turn tries to keep the COM between the two legs (figure 6).
This protective stability habit blocks the spatial orientation how to control the trajectory of the body and the natural edging and builds a symmetrical stance, where both legs are forced to get into a pushing stance.
The symmetric stance and the pushing habit in the turn predispose the A-frame. The two common way of the edging is:

- moving the COM to the centre of the ski
- A-frame.

In the beginner's lessons, we have to decide which movement program will get into memory as a basic habit.
This protective stance can be overdriven with a learned spatial control to come over the inside leg (but not closer to the centre of the turn).

Figure 6. COM changes

This positioning of the COM over the inside/downhill ski can be done with the active muscle tension of the gait chain's swing phase. Similarly, in the transition, the approaching of the COM to the downhill leg can be helped with the same muscle tension.
Additionally, this pattern of muscle activity can help to establish the anticipation and the right timing:

- to control of the inside ski
- to help the transition (engaged before the transition)

The goal of natural postural habits is looking for balance. The special objective in the teaching of skiing is accepting the loss of balance and finding dynamic stability in the changing movements.

Kinetic structure of the wedge turn

Kinetically the posture in the turn is never can be the same as the stance on a flat surface. There is always some difference between the kinetic the inside and the outside legs. It is possible to distribute the load between the two legs in 50-50%, but even in this case will be a difference because of the support on the feet (medial or lateral sole).
In any turn is a functional difference between the legs. Does not make any sense to say that the outside ski carries more load, because it is true only in certain parts of the turn. In skiing the load consist of two sources:

1. Gravity.
2. Forces which pushing the skier in the new direction.

Usually, the second source is dominant. That's why there is a kinetic difference between the transition and the turn itself.

- In the transition there is no turn, persist only the gravity. There is no inside or outside leg, only uphill and downhill leg. It is possible that the downhill leg carries more load as the uphill leg.
- In the turn, the pushing forces increasing. As increscent forces become dominant, the outside leg will take the load.

So there is a constant alteration, and the body has to react to this change. The kinetic behaviour of the outside leg under the load becomes similar to the stance leg in the gait cycle. Similarly, the inside leg behaves like in the swing phase.

Generally speaking, symmetrical movements can be based on the stance and the squat. The asymmetric movements (gliding straight with asymmetric load and every basic turn) can be based on the gait.
The basic stance and straight gliding are symmetrical two-leg postures, the conditions of these motions are dynamically constant. When the trajectory of the skier differs from the fall line the posture is related to the one-leg support stance. In the turn, the extent and the direction of the acting forces permanently changing. The reactions of the body can be based on the gait.
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1.Kinetic structure

Phase	**Inside (being inside - downhill)**	**Outside (being outside - uphill)**
Build-down (Completion)	● Femur stabilization (hip adduction, lateral rotation) ● Ankle dorsiflexion ● Hip flexors ● Hamstrings	● Ankle dorsiflexors ● Hamstrings
Transition	● Ankle dorsiflexors ● Hamstrings ● Hip flexors	● Ankle dorsiflexors ● Hamstrings
Build-up	● Ankle dorsiflexors ● Hamstrings	● Ankle dorsiflexors ● Hamstrings ● Knee extensors (quadriceps) ● Knee stabilization (popliteus) ● Glutes

Apex	• Ankle dorsiflexors • Hamstrings	• Knee extensors (quadriceps) • Knee stabilization (popliteus) • Glutes • Ankle plantarflexion • Propulsion TFL • Femur adduction (TFL)

Beginners curriculum and the kinetic chains

Coordinated kinetic chains consist not only of the mechanical structure of the musculoskeletal system but of the nervous control too. Learning a motion means among others how to adapt the coordinated kinetic chains to the specific circumstances of a sport.

Adapting to the equipment

The first movements with ski equipment is a strange experience. Restricted range of motion, changed weight distribution, bigger moment, a longer lever on the feet.
This is an important phase for a beginner in which can adapt the normal motor patterns to the changed circumstances.
This adaptation period must include stance and gait habits. Practically there is no chance to build the good postures on the slope when the stance and gait skills are not transferred to the ski equipment on flat ground. On the slope, the beginner will have much bigger issues than establish a correct posture (in general unfortunately the majority of people has problems with the postural habits even in everyday life.)

Gliding straight - sagittal plane

The first gliding on the slope can be difficult:

- During a balanced stance on the horizontal ground, the COM is over the support (feet). On the slope, this stance is too back, the body should perpendicular to the slope. This stance practically results lost in the balance (falling forward). To stabilize the body it is necessary a higher level of muscle tension in the posterior chain and in the abdominal muscles.
- The beginner cannot predict how the ski accelerates and where will stop. That's why is very important to choose a terrain where breaking isn't necessary to stop.

In this stage, the beginner will adapt the postural habit (kinetic chains) to the slope in the sagittal plane. In this stage, all the movements and muscle activities are laterally symmetrical (skills of the stance and the squat). Spatial orientation is only sagittal, too.
The main goal of this stage to maintain postural skills on the slope.

Gliding straight - frontal plane

The next step is the first time when the laterally asymmetric muscle tension appears. This patterns inherited from the premotor habits of the gait: from the one-leg stance. This asymmetry is crucial for the advanced skiing techniques: this builds the base of the alternating muscle activity of the inside-outside leg and the transition. The first stage is the control of the ski boot near to the signs. This control is made with hip adductors and lateral rotators and with the dorsiflexors of the ankle.

This control is important to preserve the COM exactly over the inside leg in the wedge turn (avoiding to fall the body over the inside leg to the centre of the turn). On the other hand, this control is crucial to avoid the COM move outside from the turn.
The main goal of this stage to maintain the postural kinetic activity on the slope.

- Laterally asymmetrical postural kinetic activity, one-leg stance
- Alternating change of the asymmetric posture (left side - right side)
- Timing (build-up, build-down)

Gliding straight - light turn

The main goal of the first turns from the fall line to maintain the postural kinetic activity of the gliding in the changed spatial circumstances. During the straight gliding, the frontal plane of the body was perpendicular to the fall line, and keep unchanged compared to its environment. This is not challenging for spatial orientation.
During the turns the frontal plane of the body is parallel with the radius of the turn, ergo it changes at every moment compared to its environment. This means a bigger challenge for the spatial orientation (neither over rotation nor torsion).
The main goals of this stage:

- Laterally asymmetrical postural kinetic activity, one-leg stance in the changing spatial environment
- Timing (build-up, keep on)

First turns (wedge)

The first light turns were controlled by the postural muscle tensions. Constructing a wedge turn needs the first active movement: turning of the outside leg. This movement can be done on the base of the stable posture and of the stabilized inside leg. So the inside leg acts as a stance leg and the outside leg learns to carry the load. In an easier environment, the legs are changing the stance-swing function (as later in the transition).
The main goals of this stage:

- Transfer the one-leg stance postural activity in the turn.
- Active movements of the outside leg without retroactions in the other part of the body.
- Correct turning movement of the outside leg.

Connecting turns (wedge)

To connect two turns, it is necessary to finish the first one. In the first turn, the beginner learned to engage and keep on the correct muscle tensions to make a wedge turn until the stop. The next step is to release this muscular activity before the end of the turn: the skier will turn down to the fall line. Near to the fall line, the student can begin the next turn:
this is a passive transition. Later, at the end of the turn can engage the stabilizing muscular activity on the downhill leg (before the fall line): this an anticipated active transition.
The main goals of this stage:

- Control of the length of the turn: build down the muscular activity.
- Getting to know how the gravity controls the trajectory of the skier.
- Early engage of the being inside (downhill) postural stabilization muscular activity (anticipation, active transition).

Conclusions

The human neuromusculoskeletal (human motoric system) is based on mechanical foundations and controlled by the neurological system.

- The contraction of one muscle exerts an effect at least two mechanical parts of the system.
- In vivo never happens an isolated contraction of one muscle. Every single movement is the result of the coordinative work of several muscles. ("In gait, muscles with similar biomechanical function tend to activate in synchrony and distinct muscle synergies have been identified related to functional sub-tasks of the gait cycle (e.g., heel strike, swing).")[5]
- Those effects are combined in complex situations.
- Normal real-life movements require the harmonic movements of multiple bones and muscles.

When a muscle contracts, it exert force not only on the insertion but on the origin too. That's why the functional anatomy can describe the function of a muscle by a condition of a fixed origin. E.g. m. rectus femoris extend the knee when the pelvis and the femur are fixed. When the femur is not fixed it flexes the hip. When the pelvis not fixed it tilts the pelvis forward. Ergo the *rectus femoris* can exert several effects depending on the activity of other muscles (or external forces):

- Knee extension
- Hip flexion - femur lifting
- Hip flexion - anterior pelvic tilt.

Anatomy can describe the functions isolated, but in real life, muscle activity is always complex. In this complex scenario, every muscle play own role:

- agonist (main activity), synergist
- fixator
- neutralizer
- antagonist

Some of these functions are naturally coordinated, some of them should be learned. The neuromuscular system is looking for the most effective variations for certain situations and not always considering a wider aspect (e.g. a whole turn or more turns in the skiing).

The concrete methods build on breaking down the objectives. In this mind-set, the obtained skills resemble LEGO pieces. Each piece can be a building block of a house, a wall or a furniture, but in a different assembly it could form a piece of an animal or an aeroplane. Similarly, in ski instruction the taught skills can be utilised on different skill levels, in different scenarios and techniques. Stabilising the pelvis or actively securing the ankle are equally useful in gliding straight, turning in a snow plough or carving with parallel skies, but it can also play a role in the dolphin-like movement of short turns.

Before transition, in the build-down phase of the turn (completion), the downhill side (being inside) becomes in focus. The extensor chain is releasing, so an important task to prevent the valgus position of the femur and another one is to engage the flexor chain (hamstrings, hip flexors) with the dorsiflexion of the ankle as a trigger. This shows a big change in the muscle activity of the downhill leg. The uphill leg does the same activity as in the middle of the turn.

[5] https://onlinelibrary.wiley.com/doi/pdf/10.1002/jor.23391

The dominant muscle activity of the inside leg (figure 7) the plantarflexion and the knee flexion almost during the whole turn. Hip flexion active at the beginning of the turn until the COM reaches the bottom position.

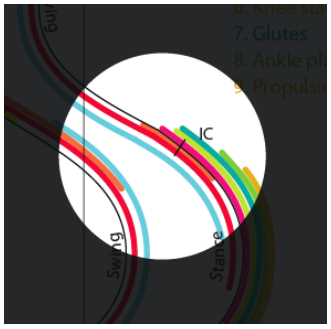

Figure 7. The dominant muscle activity of the inside leg

The extensor chain (glutes, quadriceps, plantar flexors) become engaged when the load builds up in the turn (or shortly before - anticipation). It is a reaction on the pushing forces of the turn. This is the phase when the outside leg becomes the focus.
The two legs show a completely different muscle activity, except the plantar flexors and the hamstrings. This two groups acting as a primary agonist on the inside leg and protective antagonist on the outside leg (figure 8).

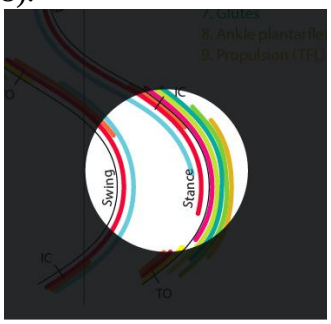

Figure 8. Primary agonist on the inside leg and protective antagonist on the outside leg.

We can assume, that this picture can be similar to the parallel turns. The amount of muscle work and the timing can change in the case of higher speed and bigger load. In the turn, under the load, the difference between the two legs can be less. The outside leg can use higher tension in the flexor chain, the inside leg can carry a bigger amount of the load with the extensor chain.

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