
# TECHNIQUE DEVELOPMENT THEORY MANUAL

# Technique Development Theory and Technical Report Card Manual

**ACKNOWLEDGEMENT**

This manual was produced through the collective efforts of National Team coaches from Biathlon Canada and Nordiq Canada, with further contributions from Nordiq Canada's sport development division.

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Canada

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## 3.1 TECHNIQUE MANUAL AND THE TECHNIQUE REPORT CARD

Nordiq Canada is committed to creating a clear and effective method to communicate and evaluate the technique that is required for world class performances to all our members. The following is Nordiq Canada's revised Technique Manual and associated Technical Report Card which will allow coaches, directors, skiers, and IST to communicate in one common language and provide consistency and appropriate development progression across the Podium Pathway. It will also inform our Skills Development Programs and Ski Playground resources.

The intent of the completed report card is to inform program and periodization of the pillars within the Gold Medal Profile. Gaps identified in the Technical Report Card are then addressed through mitigating strategies in a skier's yearly training program.

**Technique Manual:** The reference point for the basic biomechanical principles and terminology for cross-country skiing technique in Canada.

**The Technical Report Card (TRC):** A standardized tool to develop technique through measurement, analysis, and evaluation.

**Goal:** Define **what** good technique is, and **why**.

There are two (2) factors that contribute to skiing faster/at a higher speed/velocity (V)[1]:

Velocity is equal to distance divided by time: (V=d/t)

- **Increase cycle length =** cover more ground/distance (d) from pole plant to pole plant
- **Increase number of cycles per time =** higher tempo/frequency. In other words, complete the cycle in a shorter period of time (t).

For the greatest gains, skiers want to do both, increase the distance you ski in one cycle and complete the cycle in less time.

## HOW TO TRAIN FASTER SKIING

1. **Improve technique = use energy more effectively**. Improve the force producing movements and timing of movements. *This is the target of this manual and TRC*. Essentially, direct all our applied force/energy in the direction we want to travel. If we want to go straight forward, any sideways or twisting energy would be considered wasted and our technique less effective. We have gas in the tank, but it's leaking, and our

1. [1] *(Losnegard, Myklebust, Ehrhardt, & Hallén, 2016; Holmberg, Lindinger, Stöggl, Eitzlmair, & Müller, 2004)*

steering wheel isn't pointed straight.

2. **Improve fitness (strength and endurance) = more energy potential.** Improving the skier's $VO_2$ max, endurance and other physical abilities. We would be starting with more in the gas tank and have a better delivery system of getting that gas to the engine!

A combination of the two points above will lead to a faster and more efficient skier.

Part of the art of coaching is for the coach to determine which of the various variables to prioritize for each skier. Some skiers respond quicker physiologically than other, some increase strength quicker than others and some are better at coordinating their movements and making changes to their technique quicker. All areas should be continually worked on.

**This manual focuses on Part 1 – Improving Technique.**

## How is Good Technique Defined?

Good technique is one that is effective and efficient, maximizes an individual skier's strengths, minimizes a skier's individual weaknesses, and reduces the chance of injury.

Every skier is different whether physically, physiologically, or mentally, each with their own strengths and weaknesses so there is no one, single technique that is perfect for everyone and no one single technique per skier either. As a skier grows and develops, so will a skier's technique.

There will still be a "perfect" computer model for what each skier's technique should look like based on current strengths and weaknesses, body type and other external variables such as course, environment, equipment and conditions. As these variables change, so will the "perfect" model for that particular skier.

How do we determine if a skier is close to their current "perfect model"?

1. **Measure effectiveness/energy used.**
    - Using a roller ski treadmill to measure energy consumption. (Usually measured by oxygen usage). Skiers using less energy for the same demand (constant incline, speed, and equipment) execute technique more effectively than other skiers.
    - Using IMU units to measure speed (m/s) in conjunction with HR monitors and video analysis. An inertial measurement unit (IMU) is an electronic device that measures and reports a body's specific force, angular rate, and sometimes the orientation of the body, using a combination of accelerometers, gyroscopes, and sometimes magnetometers
    - Repeating field tests on consistent terrain by measuring speed and HR

2. **Analyze the best skiers.**

- In the lab or in the field, we can record and objectively analyze skiers. By comparing the fastest elite skiers to those at a lower performance level, we can identify patterns that suggest more optimal technique. This is the most used method to identify what we think is a better way to ski. Analysis is carried out by either scientists or observations in the field by skiers and coaches.
- **Caution**– what a top skier is doing does not always mean it is what they are trying to do. *Coaches need to be mindful to compare apples to apples and compare a skier to another skier of similar size, shape, age and other strengths and weaknesses. For example, comparing a 6'2" skier to a 5'8" would be unfair. The taller skier would have longer limbs (levers) which would allow for a technique to be used that takes advantage of the additional length of each limb. Comparing a 6'2" skier with an upper/lower body split of 50/50 would also use a different technique than a 6'2" skier with a 35/65 split (longer legs and shorter torso). You also need to be careful comparing what you think look like the same apples, because one apple might have bigger seeds and a larger core in the middle (Physiologically, a young skier will be built quite differently than an older skier that has had more "time on the snow", and will have a more efficient nervous, cardio, and muscular system that allows them to take liberties with their technique).*

# TECHNIQUE REPORT CARD (TRC)

Nordiq Canada has developed the Technique Report Card as a standardized method of monitoring and evaluating technique nationally. This section introduces the Technique Report Card and its purpose. The remainder of this manual discusses the principles of good technique.

A complete image of the TRC is available further down.

The Technique Report Card is broken down into 2 main sections:

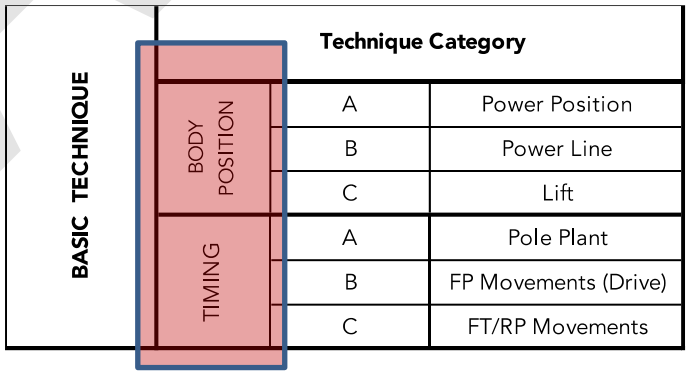
1. Technical Assessment
    a. Basic Technique Section
    b. Basic Technique
2. Tactical Assessment

## TECHNICAL ASSESSMENT

Starting at the top left of the report card is the Technical Assessment.

The Technical Assessment is divided into two main categories:

- Body position
- Timing



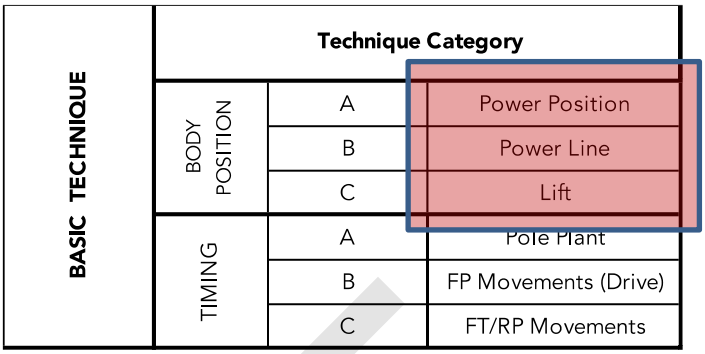

## BODY POSITION

These categories take into consideration all the biomechanical principles discussed in the following sections.

The Body Position is further subdivided into three subcategories (A, B, C).

Body position is broken down into three subcategories:

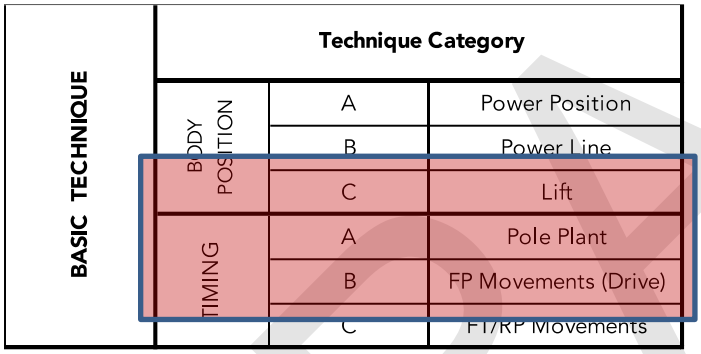
A. Power position
B. Power line
C. Ski liftThe body positions are the foundation. They are the starting positions and end goal of the movement. These categories are principles that apply to both classic and skate, and their sub techniques.




## TIMING

The previous section focused on establishing the desired body positions to look for in the cycle.

Timing examines the rhythm and movement between those positions.




The Timing is further subdivided into three subcategories (A, B, C).

Timing Section is broken down into three subcategories:

A. Pole Plant
B. Force Producing (FP) Movements (Drive)
C. Follow Through (FT) and Repositioning (RP) Movements

## BASIC TECHNIQUE FOCUS

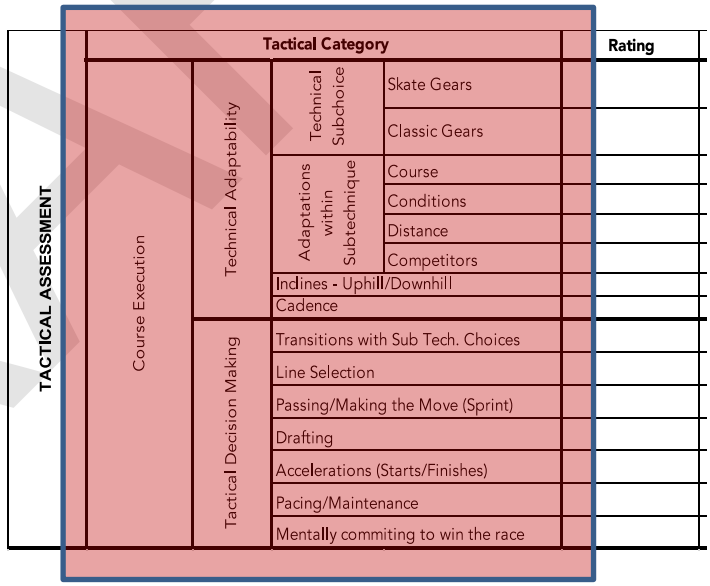
This section expands on the Basic Technique section above and elaborates on one or two things that the skier is focusing on in each technique at a time. It is recommended that the skier has only two focuses for each technique: one Body Position and one Timing related.


The comment box is meant as the cue that skiers are supposed to think of to elicit the wanted change. This should be based on a discussion with the skiers, so that the skier knows exactly what that cue means. This comment box can be updated as often as the coach and skier see fit, but the technique category focus stays the same until the next time an analysis and grading process has happened.

## TACTICAL ASSESSMENT

This section evaluates the ability of the skier to use all techniques and sub-techniques in a tactical manner.

**This manual does not cover the expectations of this section and will be discussed in other coaching materials.**



# NORDIQ CANADA TECHNICAL REPORT CARD

| | | | | | Classic | | | Skate | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Technique Category | | | Striding | Kick DP | Double Pole | Offset | One Skate | Two Skate |
| TECHNICAL ASSESSMENT | BASIC TECHNIQUE | BODY POSITION | A | Power Position | | | | | | |
| | | | B | Power Line | | | | | | |
| | | | C | Lift | | | | | | |
| | | TIMING | A | Pole Plant | | | | | | |
| | | | B | FP Movements (Drive) | | | | | | |
| | | | C | FT/RP Movements | | | | | | |

| | | Sub Technique | | Tech Category Focus | | Comments |
|---|---|---|---|---|---|---|
| TECHNICAL ASSESSMENT | BASIC TECHNIQUE FOCUS | CLASSIC | Striding | Body Position | | |
| | | | | Timing | | |
| | | | Kick DP | Body Position | | |
| | | | | Timing | | |
| | | | Double Pole | Body Position | | |
| | | | | Timing | | |
| | | SKATE | Offset | Body Position | | |
| | | | | Timing | | |
| | | | One Skate | Body Position | | |
| | | | | Timing | | |
| | | | Two Skate | Body Position | | |
| | | | | Timing | | |

| | | Rating | Comments |
|---|---|---|---|
| TECHNICAL ASSESSMENT | Overall Technical Efficiency | | |

| | Tactical Category | | | | Rating | Comments |
|---|---|---|---|---|---|---|
| TACTICAL ASSESSMENT | Course Execution | Technical Adaptability | Technical Subchoice | Skate Gears | | |
| | | | | Classic Gears | | |
| | | | Adaptations within Subtechnique | Course | | |
| | | | | Conditions | | |
| | | | | Distance | | |
| | | | | Competitors | | |
| | | | Indines - Uphill/Downhill | | | |
| | | | Cadence | | | |
| | | Tactical Decision Making | Transitions with Sub Tech. Choices | | | |
| | | | Line Selection | | | |
| | | | Passing/Making the Move (Sprint) | | | |
| | | | Drafting | | | |
| | | | Accelerations (Starts/Finishes) | | | |
| | | | Pacing/Maintenance | | | |
| | | | Mentally commiting to win the race | | | |

## 3.2 Definitions and Terminology

**Acceleration:** refers to the rate of change of velocity.

- Acceleration in skiing is usually measured in metres per second per second ($m/s^2$).
- A skier with positive acceleration (observed in the poling/push phase) increases ski speed. A skier with negative acceleration (observed during the glide) loses speed.

**Aerobic Fitness:** the measure of a skier's ability to take in oxygen and convert it to energy. The greater a skier's aerobic fitness, the greater the skier's ability is to exert energy over the longest duration of time.

- A higher level of aerobic fitness will allow the athlete to maintain good technique longer.
- $VO_2$ max is a measure of aerobic fitness.
- In other words, the greater a skier's aerobic fitness, the greater their gas (oxygen) mileage.

**Balance:** a state of physical equilibrium. A skier is balanced when their COM is aligned over the base of support.

**Base of support:** The base of support, as it applies to a cross country skier is the area between all points of contact with the snow

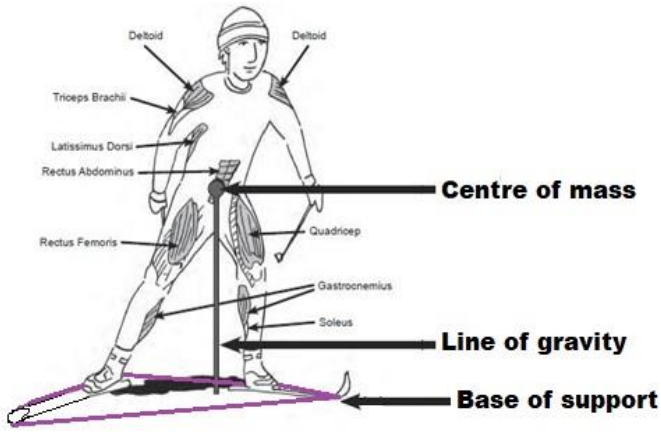
- In cross-country skiing the base of support is more often than not a single narrow ski.

**Cadence:** the number of cycles (see definition below) per time.

- It is the pace of which technique is executed
- Often expressed in cycles/minute, cycles/second, etc.
- One way to increase ski speed is to increase cadence

**Centre of Mass (COM):** is the imaginary point at which the mass of the skier or object may be thought of as being concentrated. The point around which the mass and weight of a body is balanced in all directions

- COM is not a static point. As the skier changes their shape and changes the distribution of their mass, the COM will change with it.
- Also referred to as Centre of Gravity




**Core:** The term used to describe the general area of the skier's upper body between the shoulders and the hips.

- Includes all the abdominals, chest, and back muscles

**Cycle:** Defined from one pole plant to the same pole plant again.

**Efficiency:** Using the least amount of energy possible to ski a predetermined distance.

- Efficient technique means the skier has directed the majority, if not all of their applied force in the

direction they want to travel.

**Force:** is the strength or energy a skier generates and uses to move across the snow.

- $F = m \bullet a$
- It has magnitude and direction
- Often a push or a pull created by flexion/extension of the joints.

**Friction:** is the resistance to motion created by contact between two surfaces.

- The magnitude/size of this resistance, as it applied to cross country skiing is dependent on five factors:
    - The wax on the skis and the properties of the snow
    - The irregularities on the surface of the ski or the snow
    - The weight of the skier
    - If the skier is moving or not
    - The speed at which the skier is moving

**Glide:** the movement of a skier on a supporting ski or skis when not pushing/pulling with the legs or the poles.

- Occurs between the completion of the poling phase and beginning of the leg drive.
- Since the skier is not applying force to the ground, the skier is slowing down due to air resistance and the friction of the skis on the snow.

**Impulse:** Application of force over a period of time

- Impulse = Force · time
- A skier must apply an impulse to the ground to accelerate and increase their speed. Refer to section 3.3.3 Principle of Impulse for more information.

**Joint Range of Motion:** Refers to the amount of movement at a joint.

- Measured in degrees.

**Leg Drive:** The active motion of the leg moving down and behind the skier's centre of mass with the goal of driving COM forward.

- Often referred to as the kick or leg push.

**Line of Gravity:** This is an imaginary line passing straight down through the centre of mass to the ground.

**Momentum:** is a measurement of mass in motion: how much mass is in how much motion. It is usually given the symbol **p.**

**Pole Plant:**

**Power:** Power is a measure of the speed force applied and is a common term used by practitioners, however not always correctly.

**Power = Force x speed (distance/time)**

- In cross country skiing, power is generated by exerting force over the greatest distance possible over the shortest period of time.
- A skier's ability to generate power is dependent on body position, body movements, timing, strength,

and flexibility.

**Pre-Loading:** a flexion of the joints (ankle, knee, hip) putting muscles under tension and allowing for extension and force production.

- This flexing puts the muscle under tension and initiates the 'stretch reflex' using the elastic energy of that muscle to generate force.

**Rhythm:** The timing and pattern of movements observed over a complete ski cycle.

- Rhythm of a skier is determined by individual technique, ski technique/sub-technique being executed, snow conditions and type of terrain.

**Speed:** is the measure of how fast a body is moving.

- Measured in meters per second (m/s).
- As it applies to cross country skiing, speed is greatest when a skier covers the greatest distance over the shortest period of time.
- Speed = distance/time
- Sometimes referred to as velocity.

**Stability:** the ability of a skier to maintain position and alignment in both static (motionless) and dynamic (while moving) situations.

- In the ski cycle, there are times it is advantageous to be a position of instability. Refer to section 3.3.1. Principle of Stability for more information.

**Timing:** refers to when one technical movement begins in relation to another.

- An example would be the timing between the onset of the poling phase in relation to the onset of the leg drive.

**Weight Shift:** Weight shift is the movement/shift of the centre of mass (COM).

# 3.3 PRINCIPLES OF BIOMECHANICS

There are 4 biomechanical principles that are particularly relevant to the analysis of cross-country ski technique. By referring to these principles you will be better able to analyze individual skier technique and make more accurate observations about what changes are necessary to improve individual performance.

## 3.3.1 PRINCIPLE 1: STABILITY

***Maximum stability requires a low centre of mass, a wide base of support, and the centre of mass within the base of support.***

Cross country ski technique, as with all sports, is the constant cycle of stability to instability to stability repeated. There are times through the ski cycles, regardless of technique being used, when the objective is to maximize stability, but also times when the objective is to be "unstable" but still in control. The goal is to do so with as much efficiency and control.

There are four aspects of stability which a coach can observe when analyzing skiers, all of which can be manipulated depending on the objective of the skill being analyzed.

1. ***Height of the centre of mass:*** The lower the centre of mass, the more stable the skier.

| Objective | Example | Description |
|---|---|---|
| Maximum Stability | Skiing down hill | The skier wants to maximize stability to prevent falling, and wants to be more aerodynamic. The skier will decrease the height of their COM by bending at the hips, knees and ankles. |
| Instability | Double poling | Raising the COM helps the skier create a greater position of instability. The skier will fully extend at the hips, knees, and ankles, raising the COM. The skier also maintains a forward leaning angle of the core and brings the arms forward, moving the COM forward. As gravity now pulls down on the COM, the angle created by the lean of the core creates a vertical and horizontal force. The horizontal force is applied backwards which help propel the skier forward. The greater the forward lean, the greater the backward force applied. |

2. ***Area of the base of support (BOS):*** The larger the BOS, the more stable the athlete is.

| Objective | Example | Description |
|---|---|---|
| Maximum Stability | Broaden BOS by spreading skis wider apart on downhill | Skiers who require greater stability on downhills will broaden the BOS by keeping their skis further apart. This will provide greater stability in the frontal plane (from left to right) and the skier will be able to maintain stability even if the COM moves from side to side by providing a larger distance the COM can move before nearing the edge of the BOS. |
| Instability | Timed sprint start | The athlete initially starts with the poles outside of the start gate allowing the skier to shift their COM closer to the front of the wax pocket without falling forward. However, once the athlete wants to accelerate forward, the poles are immediately picked up, which narrows the BOS, creates a position of instability which allows for the skier to move forward quicker. |

3. ***Position of the COM in relation to the base of support:*** To increase stability, the COM should be as far as possible from the edge of the BOS.

The centre of mass must be within the base of support for the athlete to be balanced. In other words, the line of gravity must fall within the base. If an athlete's centre of gravity moves outside of the base of support, or if it deviates sufficiently to one side or other of the line of gravity, balance will be lost.

Loss of balance is not necessarily undesirable, nor does it imply that stability will be lost as well. It is often necessary and/or desirable to "lose balance" in order to initiate weight shift and create momentum. Provided that the loss of balance occurs in a controlled manner and results in a return to a balanced position at the end of a movement, stability is retained.

| Objective | Example | Description |
|---|---|---|
| Maximum Stability | Leaning into a turn on a downhill | If turning right, the skier should shift their COM over the right ski, as the curvature of the turn will want to push the COM to the left. By shifting the COM over the right leg, the skier effectively increases the distance the COM must travel to fall outside of the left edge of the BOS (outside edge of the left ski) before the skier would lose stability and ultimately fall. |
| Instability | Offset | When skiers swing their hands forward and step up the hill onto a new gliding ski in the Offset technique, they are clearly in a provoked state of disequilibrium/instability. Until the new gliding ski is on the snow and the COM has been shifted onto it, they are falling forward and to one side because their COM is outside the BOS (i.e. the pushing ski). This position of temporary instability |

| | | |
|---|---|---|
| | | facilitates the shift of the COM to the side they are leaning toward. |

***4. Mass:*** To increase stability, increase mass.

| Objective | Example | Description |
|---|---|---|
| Maximum Stability | Let skiers celebrate together first | When you go to celebrate with your skiers after winning the relay race, wait until they are embracing each other. That way, when you jump onto the pile, you are less likely to topple the pile of skiers to the snow. |
| Instability | Drop all equipment first | If the skier is coming over to celebrate with you and you are happy to fall in the snow (likely due to exhaustion), drop all external equipment (extra ski poles, water resistance phones, gloves, toque, make yourself as light as possible, so when the skier comes to tackle you in celebration, you will topple over and can finally take a nap 😊 |

**NOTE:** Having a skier increase or decrease mass is more a physiology and finding the optimal power/weight ratio of each individual skier is not a decision made for the purpose of changing biomechanics.

### 3.3.2 Principle 2: Producing Maximum Force

***Maximum force skills require the use of all the joints that can be used in order from larger to smaller***

Skiers require a large amount of force and the development of large speeds in the limb segments. Understanding how to produce maximum force will help a coach determine how to capitalize on individual skiers' strengths and weakness and determine what the optimal combination of movements will yield the most efficient technique for each skier.

The production of maximum force consists of 2 general principles:

- The use of all the joints that can be used and;
- To use every joint in order from larger to smaller.

***Use all the joints that can be used:*** The more joints a skier uses in a movement, the more muscles they can recruit and contract, and the greater the sum of force they can exert to the ground. Joints that are being used should be used in their appropriate range of motion in a biomechanically sound position.

When executing the poling action in a Double Pole movement, the athlete should engage the: hips, knee, ankle, shoulders, elbow joints.

***Use every joint in order from larger to smaller:*** From proximal (closest to COM) to distal (furthest from COM). Newton's second law of motion states that forces produced by muscles cause the segments to move faster or accelerate.

Cross country skiing requires many joints to move through a large range of motion, at high speeds to create the greatest force possible. This high speed is attained by the summation of the individual speeds of all preceding segments (segments are defined as the part of a body from one joint to another. E.g., elbow to wrist) with the appropriate timing.

The summation of forces typically starts with the larger, slower joints beginning the movement then the faster joints contributing when the preceding joint reaches peak speed.

The example above regarding the joints used in the double pole movement should therefore occur in the following sequence: Engage hips, knees, ankles.

***Stabilize joints that are not used to generate force***. Minimize force dissipation.

### 3.3.3 Principle 3: direction of Force Application

***Force must be applied in the opposite direction of the desired motion***

This principle is related to Newton's Third Law of Motion, which states that every action has

an equal and opposite reaction. Coaches must carefully examine the direction of the application of force by their skiers. If the goal is to travel forward, then the more force a skier can apply directly backwards, the more efficient the technique.

Timing the extension of the joints correctly to wait until the COM is in front of the joints first to create greater horizontal forces and less vertical forces, resulting in less vertical movement of the COM. If a coach observes a "bobbing" motion when analyzing the technique of a skier, this is an indication that the skier is extending their joints too early and is creating excessive vertical movement of their COM. This is one of the reasons why we do not see a large vertical displacement of the COM of elite skiers, because they have excellent timing and are efficient!

**NOTE:** Considering an athlete must maintain friction of the snow, and friction is increased by increasing vertical forces, there will always be a certain amount of force directed downward, a skier cannot just push horizontally (Classic ski set). As this is a required direction of force application, it is not considered wasted energy. Therefore, an efficient technique is one in which the necessary amount of force is directed vertically downward, and the remaining force is directly as horizontal as possible.

Examples of mis-directed force (and less efficient ski technique):

- Ski slipping
- Large displacement of the skier's head (bobbing up and down)
- Follow-through of ski poles travels out to the side in diagonal stride

### 3.3.4 PRINCIPLE 4: IMPULSE AND MOMENTUM

***The greater the applied impulse, the greater the increase in momentum which means the greater increase in speed.***

- Impulse (J) = Force (F) x time (t).
- Momentum (p) = mass (m) x speed (v).
- We know that Force = mass x acceleration, and acceleration is change in speed over time.
    - Insert fancy math and you see that **IMPULSE = CHANGE IN MOMENTUM**
- ***Increase Impulse means increased momentum which means increased speed.***
- To increase impulse:
    - Increase the force applied
    - Increase the time over which the force is applied
    - Increase both.
- Balance between Impulse and range of motion - finding the optimal balance of the acceleration and deceleration.

In cross country skiing we focus on the application of force more than the 'time' of application.

Although mechanically true, impulse can be increased by applying the same amount of force over a greater period of time, **BIO**mechanically, this is not true in the application of forces by the human body.

It has been found that muscle contractions are more forceful when they occur over a very short period of time, so skiers who are able to apply their forces over a shorter time will produce a larger impulse and greater increase in speed.

Coaches should focus on maximal force application and applying force through a large range of motion, quickly.

***Joint range of motion and impulse:*** When a skier requires maximal application of force, the joint(s) should be moved through a large range of motion allowing the muscles of the joint to generate force through a larger stretch-shortening phase. The range of motion the skier should have at each joint will be dependent on the speed of the skier, their flexibility, their strength and the terrain and other external factors.

- Skiers should be instructed to apply maximal amount of force through the largest range of motion as fast as possible. ***Greatest range of motion over the shortest period of time.*** This is by the very definition, is power (Power = Force x speed (distance/time).

***Impulse and Force Absorption***. There are times during cross country skiing that a skier **wants** to absorb force **instead of producing it**. One example would be going over bumps on a downhill.

- The skier **wants** to absorb the upward force that would be created by going over a bump by allowing

the hips and the knees and the ankles to flex more, keeping the COM moving horizontally and not vertically.

- Absorbing force through a range of motion of joints that should be otherwise held stable. For example: shoulder shrug at pole plant – force, and therefore impulse, is not transferred to poles, but absorbed through the movement of the shoulders. This results in loss of impulse, lower momentum change, therefore lower speed at end of force producing movement.

# 3.4 QUALITATIVE ANALYSIS

## 3.4.1 SKILL PHASES

The ability to analyze skills qualitatively is improved if the skill is broken down into smaller parts. These smaller parts can then be analyzed separately, and the appropriate corrections made. One way to break a skill into smaller parts is to break it down into phases that have a specific purpose and contribute to the overall success of a skill.

The most common way to break down a skill for qualitative analysis include the following 4 general phases:

**Repositioning Movements.** The movements made just prior to the force producing movements:

- The repositioning of the arms and legs as they start moving forward.
- The repositioning of the core
- The pre-loading of a leg

At the end of the repositioning movements, the skier should be in the **power position** and the **power line** should be established.

**Force Producing Movements.** These are movements that an athlete executes to produce force for the purpose of propulsion.

- The leg drive (kick)
- Pole push in double pole

The **power line** should be observed throughout this phase of the skill.

**Lift.** This is the point where you can no longer increase or change the direction of force, and you can no longer increase your speed. It signals the end of the force producing phase.

- This is the Pole or ski lift
- Everything after this point means you are slowing down

**Follow-Through Movements.** Referred to as the body movements once force application is done before repositioning starts after the pole/ski lift.

- Follow-through actions provide useful information about the force producing movements.

Understanding that every skill needs to meet the goal of at least one of these phases, helps us determine if an observed movement is necessary, and if it is being executed effectively and is contributing to the overall success of the skill.

The identification of these phases is somewhat unique to each skill, so we will go through the purpose of each phase in cross country skiing.

## Reposition Movements.

During this phase of the skill, the athlete essentially repositions the body to put it in the best position possible to have an efficient and effective force producing phase. This phase has three main goals:

1. It pre-stretches all the posterior muscles of each limb and activates the elastic elements in the muscle, much like an elastic band;
2. It determines how many muscles and joints can be recruited
3. It establishes the range of motion at each joint that the skier can apply muscular force through

If the movements that need to occur during this phase of the skill are not executed correctly, it will diminish the overall potential force that the skier can produce and thus, limit the speed the skier can reach.

## Force Producing Movements

These include the poling phase and leg drive. The purpose of each of these movements is to generate and apply as much force as possible to the ground that contribute to the intended direction of travel.

As stated in Principle 3, the application of a force produces acceleration or a change in speed (Newton's 2nd law of motion). ***A skilled skier is able to accelerate through this phase by using as many joints as possible and muscles in sequential and correctly timed order, from the largest to smallest and over the largest range of motion possible. Furthermore, this force generation, when done correctly, will all occur over the shortest period of time, and the force will be applied in the most advantageous direction for the ski technique being used.***

The size of the range of motion the joints move through during this phase of the skill are dependent on the following:

- The angles each joint starts at - pre-determined by the repositioning phase
- The angles each joint finishes at – determined during the force producing phase (the length of the leg drive and the length of the poling phase).
- There are a number of variables that a coach should consider when determining the ideal position the skier should stop the force producing phase.
    - Individual strengths and weaknesses, physical, physiological, of the skier

- Size and shape of the skier
- Speed of the skier
- Skill being executed
- Snow and other race conditions - terrain

## LIFT

If all the movements of the propulsive phases are correct, the ski/pole lift will be correct, but if any of the repositioning or propulsive movements were incorrect, then these errors will be translated to the Lift. Nothing can be done to alter the direction the force was applied to the ground at pole/ski lift.

## FOLLOW-THROUGH

Refers to the body movements that occur after the lift. The goal of this phase is to slow the fast-moving body parts down gradually and help prevent injury.

Observing movements that occur during the follow-through can provide insights about the direction the force was applied during the propulsive phases. For example, if the skier's poles continue to move away from the side of the body before the recovery phase, it can indicate that the force applied through the poles was directed too far outward instead of pushing directly backward, indicating the force applied to the ground during the poling (force producing) phase was poorly directed, and subsequently, inefficient.

It is important to note that a skier can only accelerate and increase speed during the force producing phase when the skier is applying force to the ground. When the skier is not applying force to the ground, the skier is gliding and slowing down due to air resistance and friction of the skis on the snow. Timing of these phases is therefore critical. The longer the athlete spends in the follow-through and reposition phase, the longer the athlete spends slowing down. Glide phase is a balance between repositioning optimally, minimizing slowing down, and allowing the athlete to rest.

Part of the art of coaching is determining how much time each athlete should spend moving through each of these phases. Understanding the physical and physiological strengths and weaknesses of your skiers will help you determine the timing and ranges of motion appropriate for each phase, for each skier.

## SUMMARY OF EFFICIENT SKIERS

World-class skiers demonstrate the following:

A. **Skiers are aligned over their base of support – Power Line (BM Principle 1: Stability**)

B. **Skiers minimize energy loss during transition from one stable position to another - (BM Principle 1: Stability**). Maintain the power line as much as possible throughout the transition.

C. **Skiers are extended at the end of the reposition movements (BM Principle 2 Producing Maximum Force)** allowing for use of the most effective range of motion and power application through the joints and allows for optimal pole loading. Less angles at the ankle, knee, and hip joints during the follow-through indicate that the skier fully extended each joint during the force producing phase of the skill (propulsive/kick phase).

D. **Skiers have sequential muscle activation - large joints to small joints (BM Principle 2 Producing Maximum Force).** Fast skiers have a pattern of activating their muscles in a certain order, and not all at the same time. The right timing of the activation of the joints gives the skier a higher power output potential (allows them to apply greater force to the snow).

E. **Force producing movements are optimally applied in the opposite direction of motion resulting in minimal vertical movement of the center of mass (COM) (BM Principle 3: Direction of Force Application).** The fastest skiers move their body up and down less. In other words, the path of their COM is more horizontal, thus, moving in the intended direction of travel.

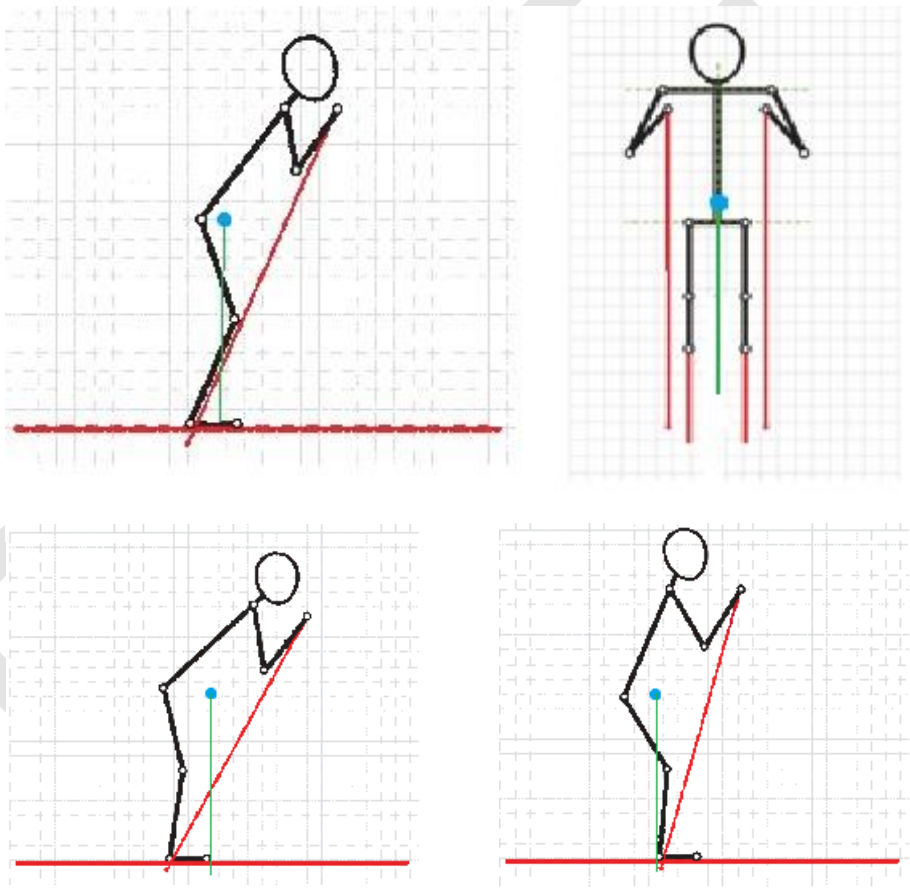
**F. Skiers apply maximal amount of force through the largest range of motion as fast as possible (BM Principle 4: Impulse).**

# 3.5 SKIING FUNDAMENTALS

## 3.5.1 General Athletic Stance.

The general athletic stance is an overall "good" body position for athletic endeavour. It is the starting position for learning or practicing most cross- country ski techniques. Its principal features are also present in many ski techniques in motion.

Image 1: General athletic stance. Diagram on the left is shown front the sagittal (side) view and the diagram on the right is shown front the frontal (front) view. The blue dot indicates the approximate centre of mass (COM), and the green line represents the Line of Gravity.



The general athletic stance includes the following:

**Feet.** The athlete's centre of mass (COM) should be over the balls of the feet. The feet should be approximately shoulder width apart. If the weight is too far forward (image #2), it will be difficult to produce a forceful leg drive. If the weight is too far back (image #3), the COM is being pushed more upwards and less forward; it does not allow for an efficient sequencing of muscle contraction (hamstrings and glutes are used to pull the ski back as opposed to driving the body forward); it requires more force for a resultant vector to compress the ski ☺.

**Ankles.** Ankles should be flexible and be capable of a degree of flexion. Ankle flexibility is important as it affects the range of motion of all the other joints above.

**Knees.** The degree of flexion that can be in the knees and still maintain stability is dependent on the degree of flexion in the ankles, but the strength and skill of the athlete will also determine the amount of flexion that is ideal at the knees. An optimal angle at the knees is one in which allows the muscles around the knees to apply force through the largest range of motion possible and best matches the skier's strength/velocity curve.

**Core/Back.** The core should keep the natural curvature of the spine, but also be rigid which is achieved by actively engaging the posterior muscles of the spine and all the abdominal muscles. This will allow the reactive forces from the ground to move directly through the COM without minimal absorption of the force through the individual joints in the spine. By maintaining the natural lordotic curve of the spine, the gluteal muscles will be put on a slight stretch which will help in recruiting the elastic energy of those muscles.

**Hips.** The hips should be flexed to a position that allows for the COM to be on the forefront of the skier's feet. If the hips are too far forward or too far back, the skier will have a less efficient force producing phase.

**Arms/Shoulders.** The shoulders should be relaxed and not hold any tension. You do not want to see the skier with shrugged shoulders. The arms should hang free and loose beside the body (Image #4). The pendulum action of the arms from this position moving forward should be smooth, driven primarily from the anterior muscles of the shoulder.

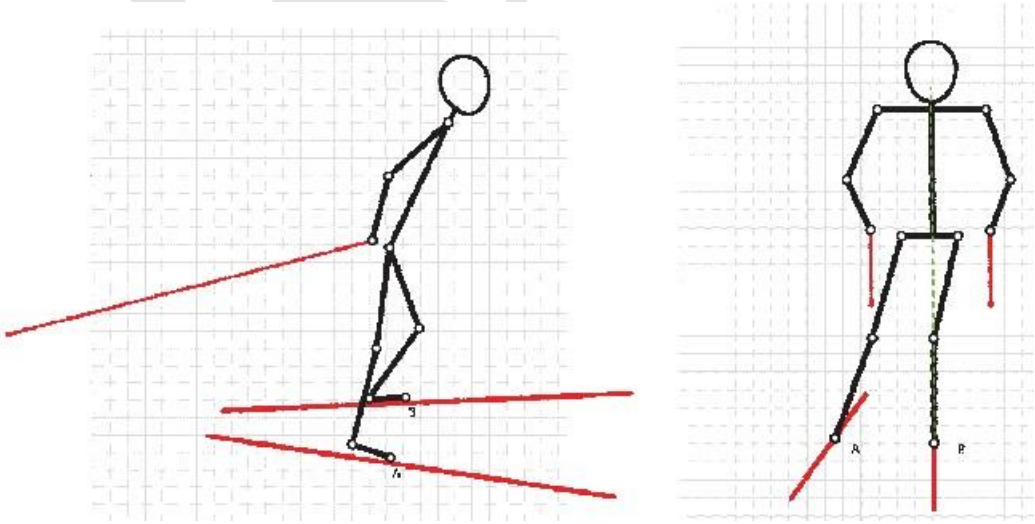


**Image 4:** Arm release (follow through of the arms) viewed from the sagittal (left) and frontal views (right) as seen in the skate ski.

# 3.6 BASIC TECHNIQUE - BODY POSITION

The body positions are the foundation. They are the starting positions and end goal of the movement. Body position is broken down into three subcategories:

- **Power position**
- **Power line**
- **Ski lift**

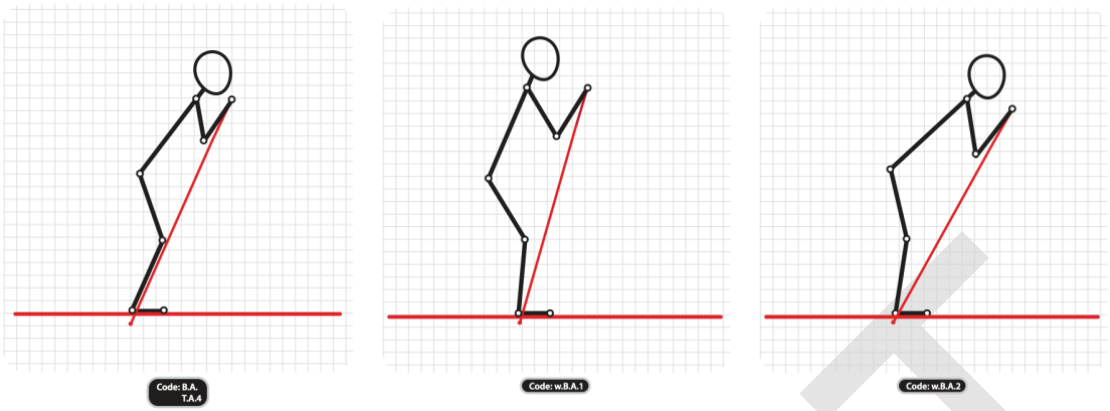
## 3.6.1 POWER POSITION

The power position occurs when the skier completes the repositioning movements and is about to begin the force producing movements. This is the point where the skier must be in the best position, from head to toe, to apply maximum force by pushing forward from leg kick/pushes and/or pole pushes, over the shortest period of time. In other words, the skier must be in the best body position to create power.

To evaluate and describe the power position, the skier is viewed from the side (sagittal plane):

- The COM (power line) is over the forefoot.
    - Biomechanical Principle 3: Direction of Force Application
- The angle in the ankle, knee and hip results in the upper body and lower legs being in approximately the same angle relative to the ground (on average the upper body has a slightly greater lean forward than the lower legs).
    - Biomechanical Principle 2: Maximal Force Application
- Optimal pole plant location depends on the speed of the skier. Remember that the skier is constantly moving past the pole plant location. Important that force is applied in the proper direction at the earliest moment. (e.g., if moving fast and pole plant is at the feet, by the time the skier can apply force, the poles are now too far back).
    - Biomechanical Principle 3: Direction of Force Application
- The arms should be flexed at the elbow and shoulder so that the hands come approximately to the level of the skier's head with the wrists remaining in neutral position.
- The head should remain in a neutral position, in line with the spine, looking forward.

All skiers have different proportions, so no one will look the same, but this is a good guideline of what to look for in this position.




The images above illustrate the power position executed in the correct way (B.A.T.A.4), and two examples of common mistakes (w B.A.1. w B.A.2).

**Image w B A.1**

The skier is in a sitting position with their COM too far back. The pole position beside the foot is now creating a braking force as it is in front of the COM. This also creates a decreased ability to load the poles effectively as there is increased vertical forces on the poles and less horizontal force than seen in the other two images. A skier in this position will require more energy and take additional time to return to the proper power position.

**Image w B A.2**

The skier is leaning too far forward and only uses the hip joint to lower the COM, instead of engaging more joints (ankles and knees) and using more muscles in sequence to create greater force producing movements. The movement to avoid is the bowing movement seen in this image.

## 3.6.2 POWER LINE

The Power Line's foundation is balance. The Power Line is drawn through the toe, knee and nose in a straight line, and the skier's hips and shoulders are horizontally level. This alignment switches side-to-side effectively with minimal loss of the power line when transferring COM from one ski to another. To achieve the most efficient gliding phase and timing for the kick, the skier needs to be fully balanced on each side. **Image B.B.1**

The power line occurs at the same time as the power position and continues through the force producing movements of the skill, but it is observed and evaluated from the front (frontal plane). Force should be directed through the centre of mass to optimize forward movement of the COM.

To ski efficiently, the skier needs to be fully balanced on each leg. Even though this principle applies to both techniques, it is a bit different in skate because of the horizontal movement of the ski away from the midline of the skier's body. This will be addressed in the "specific technique" section.

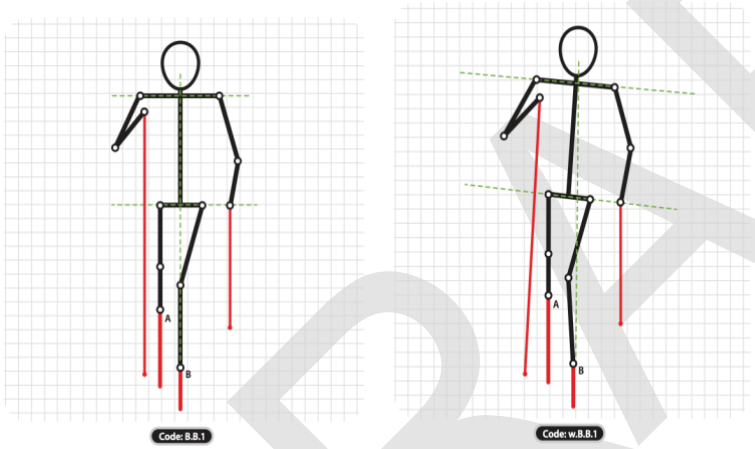



**Image w.B.B.1**

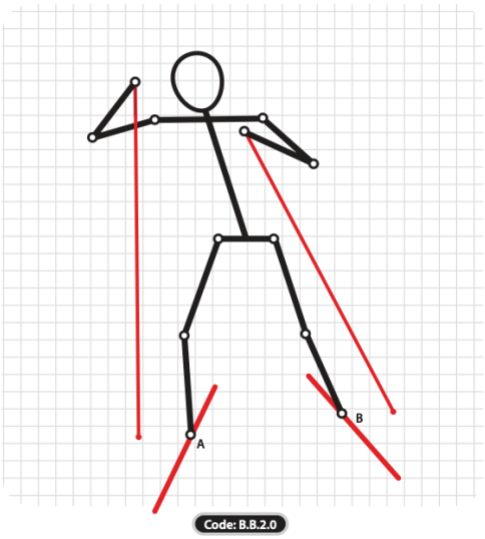
In this illustration, the skier's knee is falling in, resulting in both the hip and shoulders not being level. Although the COM is maintained, the application of force is no longer optimal.

**POWER LINE: OFFSET**

In the offset example the same principles are followed. Offset is the only technique where a slight rotation of the hips and shoulders are used to help create the force needed to move forward.

**Image B.B.2.0/Image B.B.2.1**

In offset, there is no real glide phase (because of the terrain type). Therefore, the alignment principles are maintained, however, the COM is never fully committed over the ski.



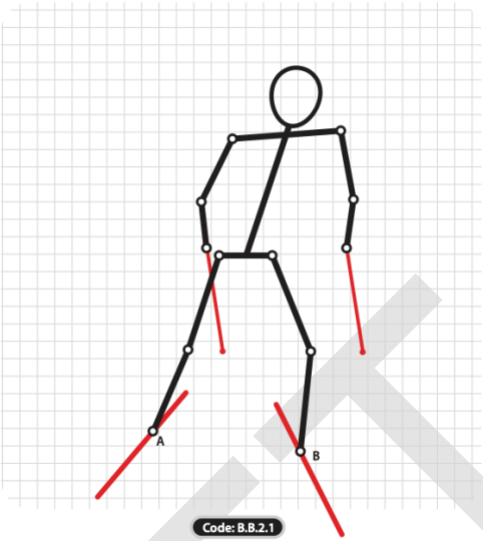
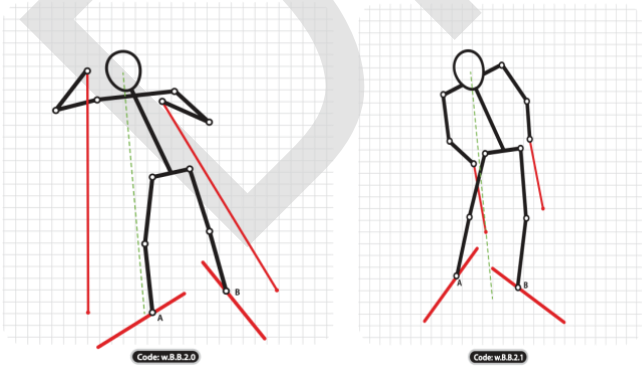




**Image w.B.B.2.0/Image w.B.B.2.1**

It is important to move the COM ahead (up the hill) and not step ahead of the COM (e.g., stepping up the hill). To produce a forward movement, the COM needs to be ahead of the force producing movements. Stepping ahead of the COM results in trying to pull the COM ahead of the force producing movements first before applying force – results in a waste of time and energy.

In the illustrations below, the skier is stepping too far up the hill with leg A and has shifted their COM too far over that leg. As a result, the skier must now take time to shift the COM over leg A to get into the power line.

Although some lateral movement of the COM is required to get into a proper power line for each leg push, the goal is to determine what the minimum lateral movement of the COM is necessary for an effective push and eliminate any excessive movement.




**POWER LINE: TRANSITION**

Look for the power line through the entire force producing movements in any ski technique, not just as a

moment in time. The skier must switch between legs by following the powerline through the leg drive, until the other leg is put down and the COM shifts over and the power line is now established on that leg.

## 3.6.3 LIFT

Ski lift is the exact moment the leg lifts from the ground at the end of the force producing movements. There are two main things to look at in the ski lift position:

- The height of the skier's COM, and
- the power line over the weight bearing ski.

**Image B.C.2.1**

This illustration depicts the desired one skate example from the side. The skier's COM is in a lower position than earlier in the power position but is still extended.

**Image B.C.2.0 T.B.4.1**

Looking at the same example from the front, the skier has moved their COM from leg A to leg B, and has established a good power line on leg B.

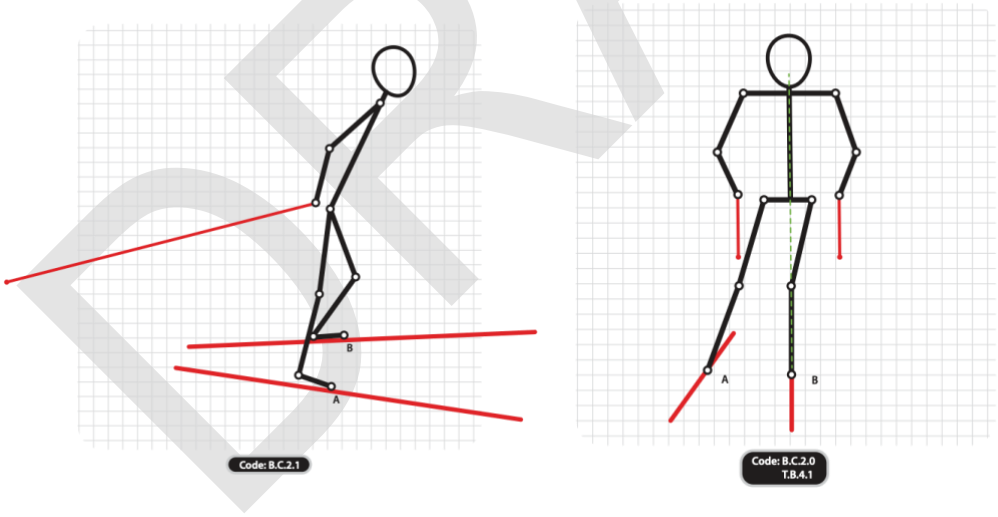
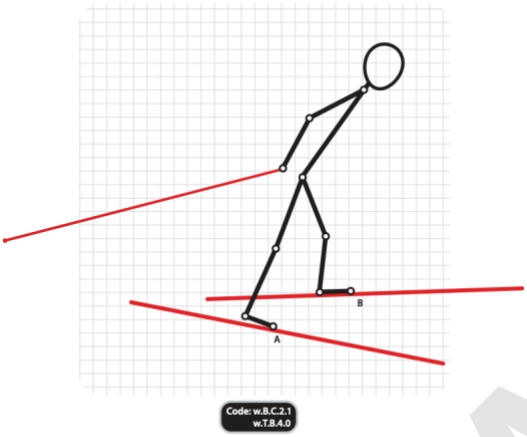



**Image B.C.2.1 w.T.B.4.0**

A common error is for the skier to have too much hip flexion because there wasn't enough flexion in the knees and ankles. By flexing more at the hips with insufficient knee and ankle flexion, the COM moves backwards. It is important to maintain relative flexion with ankles, knees, and hips.

**Image w.B.C.2.0**

Driving the push too far out to the side which means there is less force driving the COM forward, the further the leg pushes out, the more mass moves away from the midline of the skier's body, moving the COM further away from foot B. This either takes the skier longer and costs the skier more energy to get into the power line, or the skier never gets into the power line making the next leg drive less effective.



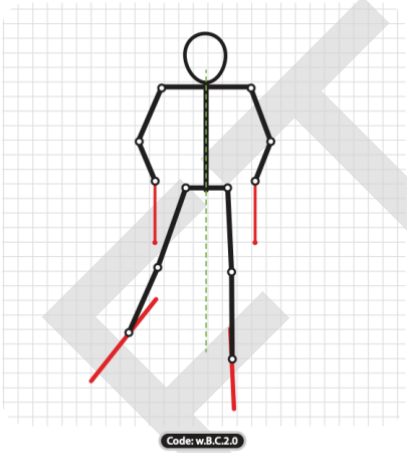




**Image B.C.1**

At lift, the skier has moved the COM fully to foot B, and will lead foot A up in the air for the glide phase on foot B.

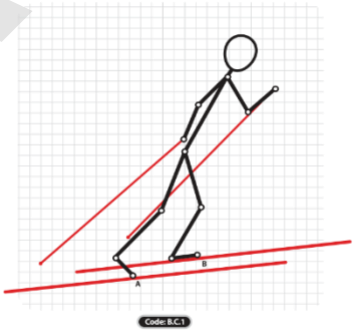
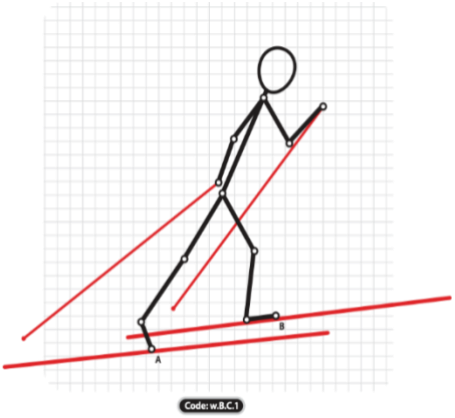



**Image w.B.C.1**

The skier has lagged with foot A. This creates two issues:

1. The further behind the leg travels behind the skier, the further the skier's COM moves back as a result the less efficient the skier is in their force producing movements.

2.Leg A now has a larger distance it must travel to get to the proper position for the next leg push/kick. In other words, it will take longer to recover the leg, take more energy to recover the leg and will ultimately reduce the cycle rate of the skier and resulting velocity.



# 3.7 BASIC TECHNIQUE – TIMING

The previous section focused on establishing the desired body positions to look for in the four phases of movement of a cycle.

Timing examines the rhythm and movement between those positions.

## 3.7.1 POLE PLANT

Pole plant is the reference point for timing.

**Image T.A.1 T.C.4 to Image T.A.3 T.C.6**

Illustration 1: Skiers lead into the pole plant through the reposition movements. The skier is coming from an almost fully extended body position and preparing for the pole plant.

Illustration 2: The body is now leaning slightly forward with the poles ready to be planted .

Illustration 3: The poles are planted by flexing the hip, knee, and ankle joints. In preparation for force application – the core maintains a stable posture (NO CRUNCH or C CURVE!!).

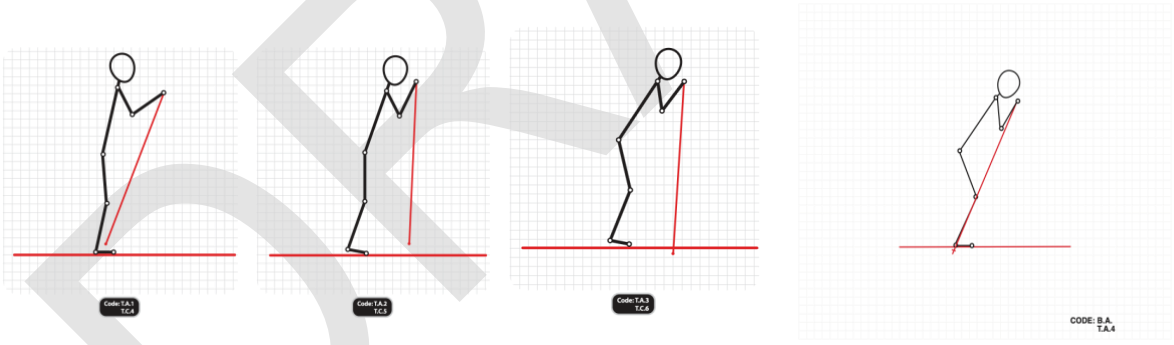


**Image w.T.A.3.1**

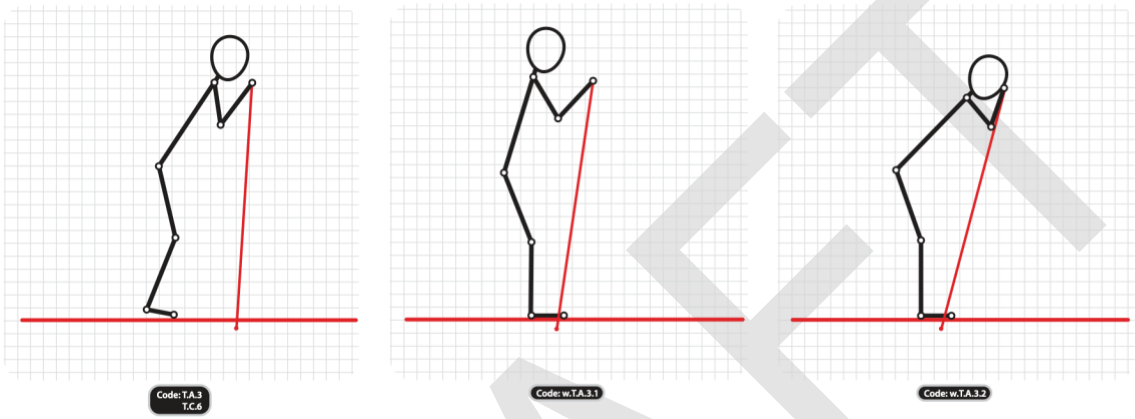
In the center example below, the skier has not been able to shift the COM over the forefoot, ending up sitting 'in the back seat' and not transferring force into the poles. This results in a decreased ability to apply force through the force producing movements. Since the skier's COM is on their heels or possibly further behind, the pole plant is now in front of the COM which means any force applied to the poles will result in a braking force until the COM moves past the tip of the poles.

The COM will move from the forefoot to the heel through the force producing movements, increasing the

range of motion leading to longer time for application of force which leads to an increased impulse as described in Biomechanical Principle 2.

**Image w.T.A.3.2**

In this example, the skier is too flexed at the hips at the pole plant and is applying the force into the ground, not getting the most out of the force producing movements.



## 3.7.2 FORCE PRODUCING MOVEMENTS (LEG DRIVE)

**Images T.B.1.0 - T.B.5.0**

The illustrations below demonstrate the skier doing One Skate focusing on the timing of the leg drive relative to the poling phase both from the sagittal and frontal planes. The sequence of illustrations shows the skier moving from the pole plant position in T.B.1.0 to the ski lift on the opposite side in T.B.5.0.

Coaches need to consider the interaction of force producing movements of upper and lower body segments.

Image 1: Body is in extension from the repositioning movements

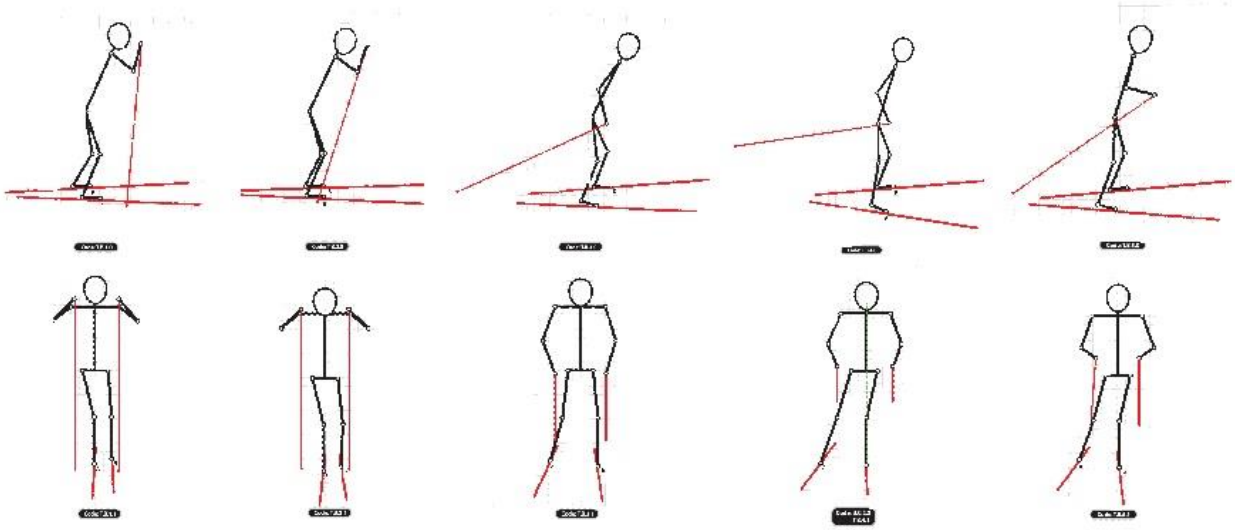
Image 2: Skier allows gravity to pull COM down by flexing through ankles, knees, hips – 'falling'.

Image 1: As poles plant into the ground – skier 'solidifies' through the upper body musculature, core – active redirection of a reactive force.

Image 2: There is deceleration of the ankle, knee and hip joints, that is observed via a small, continued ankle, knee and hip flexion.

Image 3: At the end of the deceleration of the lower body joints:

- the lower body begins its force producing movements by ankle, knee, hip extension by taking advantage of the elastic energy stored in the muscles.
- the upper body actively begins force production by rotation of the shoulders.
- the core remains rigid throughout all movements.



During the force producing movements, the skier pushes through with both leg A and both poles and drives the COM forward over ski B in a controlled movement. As the skier pushes off of leg A, the skier's COM falls outside of their base of support, creating instability. This allows the COM to be in front of the driving leg

and allows for optimal direction of the force production.

The force producing movements are complete when leg B is directly under the COM and the power line has been reestablished over leg B. This is the exact moment of the resultant ski lift for foot A.

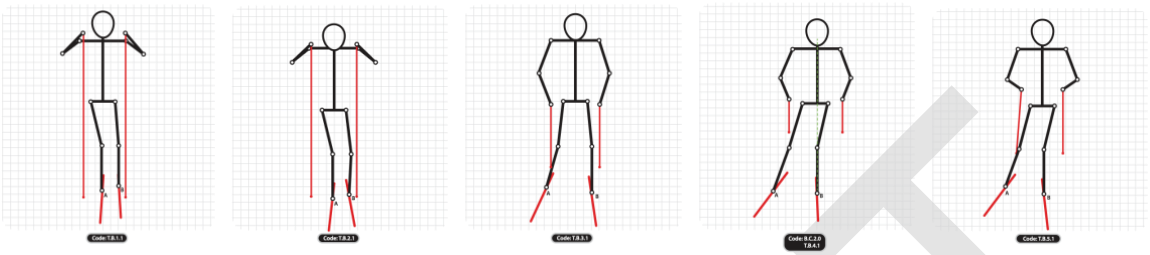
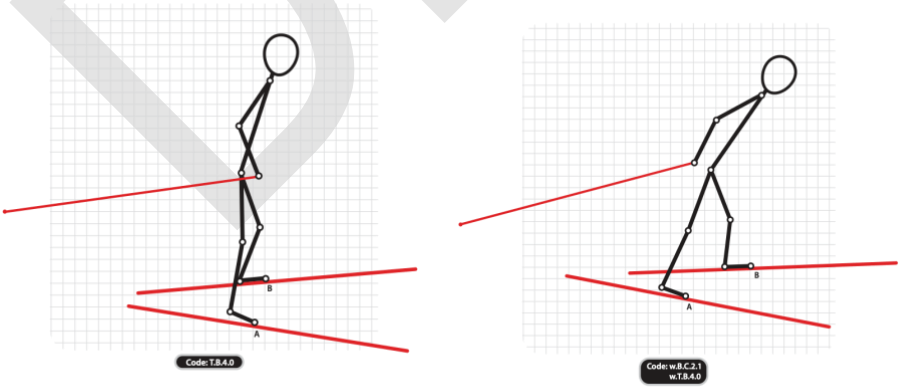


**Image T.B.4.0/w.T.B.4.0**

A common timing mistake in all techniques with a leg drive, is to over-exaggerate the range of motion of the force producing movement of the leg. As it relates to timing, this mistake results in too large of a range of motion for the reposition movements and results in the following possibilities:

- attempted force production when muscles are in a weak extended position – the force generated is not worth the energy expended versus recovering.
- longer time to execute reposition movements which often results in incomplete repositioning thus resulting in poor force producing movement preparation
- longer time to execute repositioning movements resulting in skier slowing down more and requiring greater force to recover the limb and to reaccelerate – costing more energy
- longer time to execute repositioning movements resulting in having to hold the muscle in contraction longer resulting in higher energy demand and lesser time to relax and recover



**LIFT**

At the moment of the ski lift or pole lift – the skier should be in a proper Power Line position flexed over the gliding ski.

**FOLLOW THROUGH MOVEMENTS**

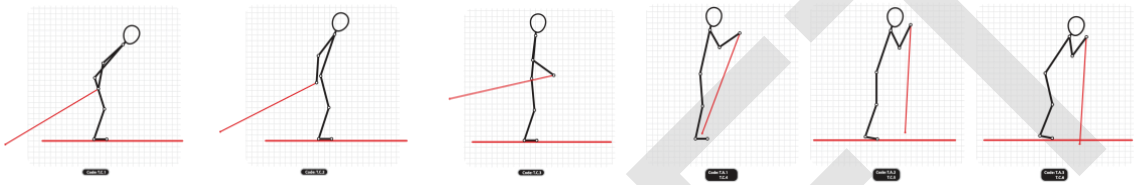
The follow through movements encompasses the deceleration of the joints prior to the start of the repositioning movements.

## 3.7.3 REPOSITIONING MOVEMENTS

**(Follow Through and Repositioning Movements)**

The focus for the repositioning movements is to set up the body position optimally for the **POLE PLANT** and force producing movements.

Images T.C.1 and T.C.2 show what would be considered the follow-through phase (as the hands continue to move backward and the COM comes forward and up in the repositioning movements. The arms decelerate and begin a repositioning movement in a forward swing. The repositioning movements end with the hands and body arriving at the same time to the Power Position.



The skier's arm swing sets the desired cadence.

## 3.8 SPECIFIC SUB-TECHNIQUES

**Diagonal Stride, Kick Double Pole, Double Pole, Skate, One Skate & Two Skate**

This section addresses the specifics of every sub-technique in classic and skate explained through the technique category system.

The sub-techniques should be looked at as a 'gear system'. What determines which gear is used is **the speed** at which the skier is skiing. The reason speed is underlined is to understand the difference between speed and intensity. Incline affects the speed that is possible to accomplish, but different conditions and efforts can make the speed very different on the same incline. The same hill can have a lot of different technical solutions depending on the distance and conditions. Female skiers on the World Cup circuit have on average 10-15% lower speed than male skiers. This results in the female skiers using the lower gears relatively more than the male skiers.

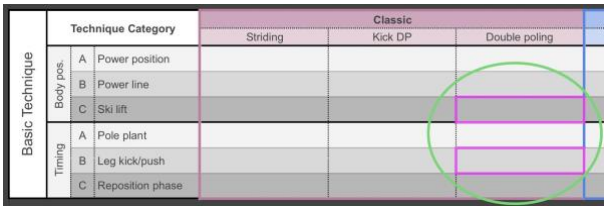
# CLASSIC

In classic technique all the movements propelling the skier forward are directed in the sagittal plane (back and forth). Side movements with the legs are limited to turns and direction changes.

Since the early 2000's double pole technique has predominated in the classic technique. There are a few reasons for this:

- Equipment and grooming have made skiing faster. Since speed determines what technique is used, higher gears, such as double pole technique, get used more.

### 3.8.1 DOUBLE POLE




The double pole stands out from the other sub techniques since it is the only sub technique the ski does not lift off of the snow.

That is why "Ski lift" and "Leg kick/push" are framed in pink for double pole in the TRC, because they serve a different purpose than for the other sub techniques.

- For "Body position - C: Ski lift" we look at the position at pole lift instead of the skis.
- For "Timing - B: Leg kick/push" we focus on the power timing through the poles around the power position.

NOTE: Double poling is the referent model for posture and movements in all techniques (where poling is applied – e.g. not free skate.)

## BODY POSITION

### A - POWER POSITION

- The COM (power line) is over the forefoot.
- The angle in the ankle, knee and hip results in the upper body and lower legs being in approximately the same angle relative to the ground (on average the upper body has a slightly greater lean forward than the lower legs).
- Optimal pole plant location depends on the speed of the skier. Remember that the skier is constantly moving past the pole plant location. Important that force is applied in the proper direction at the earliest moment. (e.g., if moving fast and pole plant is at the feet, by the time the skier can apply force, the poles are now too far back).
- The arms should be flexed at the elbow and shoulder so that the hands come approximately to the level of the skier's head with the wrists remaining in neutral position.
- The head should remain in a neutral position, in line with the spine, looking forward.

### B - POWER LINE

- The Power Line is drawn through the toe, knee and nose in a straight line, and the skier's hips and shoulders are horizontally level. This alignment switches side-to-side effectively with minimal loss of the power line when transferring COM from one ski to another.
- To achieve the most efficient gliding phase and timing for the kick, the skier needs to be fully balanced on each side.

### C - LIFT

- At the moment of the pole lift – the skier should be in a proper Power Line position flexed over the skis.

**D – FOLLOW THROUGH AND REPOSITION MOVEMENTS**

## TIMING

**A - POLE PLANT**

- Through a well-timed preparation phase the pole tips have come far enough forward for the poles to be set down from above with the entire body ready to go into the power position.
- The faster speed, the further forward the pole tips are planted, and the arms are slightly more extended from the body.
- Core activation needs to be timed so the body can hold its position as the poles hit the ground.

**B – FORCE PRODUCING MOVEMENTS (LEG DRIVE)**

- Body is in extension following the repositioning movements
- Skier allows gravity to pull COM down by flexing through ankles, knees, hips.
- As poles plant into the ground – skier 'solidifies' through the upper body musculature and core to cerate an active redirection of a reactive force.

**C – FOLLOW THROUGH AND REPOSITION PHASE**

- There is a deceleration of the ankle, knee and hip joints, that is observed via a small, continued ankle, knee and hip flexion.
- At the end of the deceleration of the lower body joints will have achieved the deepest relative flexion for that cycle
- the lower body begins its force producing movements by ankle, knee, hip extension by taking advantage of the elastic energy stored in the muscles
- the upper body actively begins force production by rotation of the arms around of the shoulders
- the core remains stable throughout all movements.

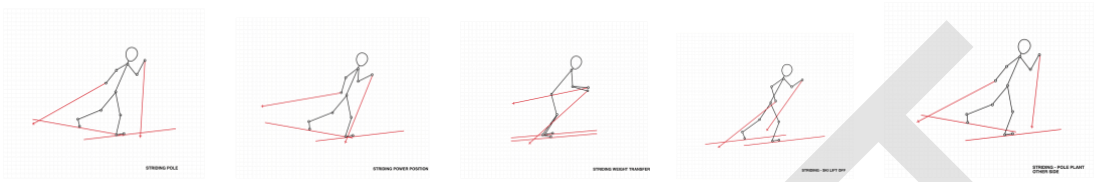


# 3.8.2 DIAGONAL STRIDE

- Diagonal stride is classic technique's first gear or low gear
- Diagonal stride is used mostly on uphills where the speed is low. Itis also used for accelerations from a

static (standing) start.

- It is the only sub-technique, for both classic and skate, where the two poles don't plant at the same time and have alternate contact times, as the pole movement is asymmetrical.



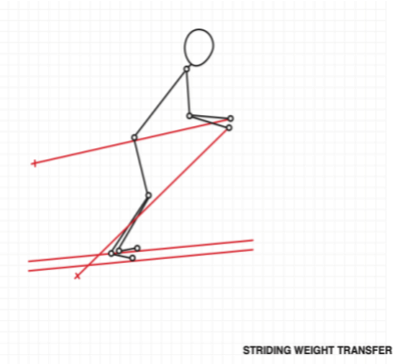
## BODY POSITION

### A – POWER POSITION

- The ankle is in an acute angle (lots of dorsiflexion) as the feet pass each other resulting in sharp forward pointing knees and flexion at the hips and full forefoot pressure. This stretches the quads and glutes and gives the knees and hips a larger range of motion that the quads and glutes can extend through and generate force and apply in a down and back direction)
- Low, forward swinging pendulum arms will contribute to the downward force generated by the lower body and will also help keep the COM over the wax pocket.
- As the skier's speed increase, the more forward the skier should lean and the greater the flexion angles should be at the hip, knee and ankle joints in order to keep the COM over the wax pocket and allow for greater ranges of motion through which force can be generated and applied.

### B - POWER LINE

- Power line is alignment of the nose, knee and toe when standing on one leg. This gives the ideal body position for a relaxed glide phase leading into optimal force production and timing.
- Shoulders and hips should remain level to the ground throughout the cycle..




### C - LIFT

- The COM should now be supported directly over or even slightly forward of the other leg, at the moment the driving leg ski lifts. this is a result of the COM now being completely/balanced over the gliding ski.
- Ski lift results from forward flexion at the ankles, knees and hips of the gliding ski as the driving leg

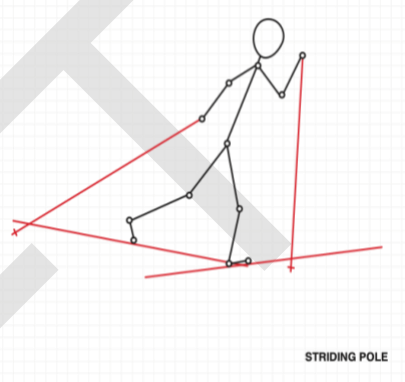
completes its force application. Ski lift requires the skier to flex the knee and the hip on the Power Line side of the body, which in turn shortens the levers about those joints and makes it easier (requires less force from the quads and hip flexors) and quicker to recover the leg and return it to ski set down.

- Ski will vary with different terrain and skier speed. The steeper and faster the tempo, the less time for gliding and amplitude of ski lift.

## TIMING

### A - POLE PLANT

- Pole plant happens at the moment the gliding leg is at its most extended and the driving leg has completed the force producing movements.




### B - FORCE PRODUCING MOVEMENTS (LEG DRIVE)

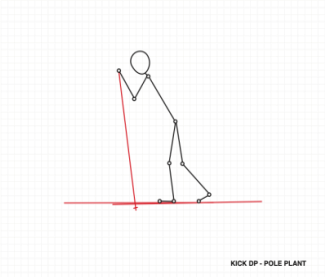
- The leg drive creates a short and rapid impulse starting from the Power Position when the front foot pressure is straight under the body, aligning the COM over the middle of the wax pocket.
- A common mistake is to overextend the kick,leaving the COM behind the binding and wax pocket resulting in potential slips and consequently, a less effective leg drive.

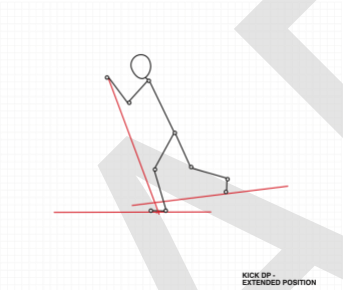
### C – FOLLOW THROUGH AND REPOSITION MOVEMENTS

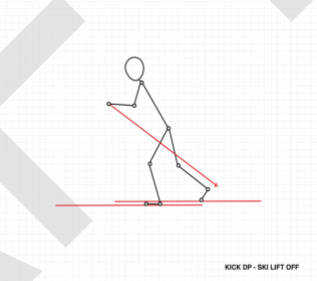
- After the driving leg completes the force producing movements, it is brought forward by the hip with a sharp knee angle (lots of flexion in the knee).
- The touchdown of the repositioning leg should happen in front of the force producing leg
- The repositioning arm/hand should pendulum low with relaxed shoulders.

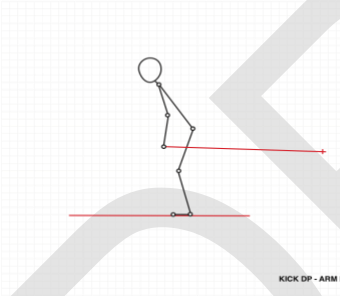
## 3.8.3 KICK DOUBLE POLE (KICK DOUBLE POLE)

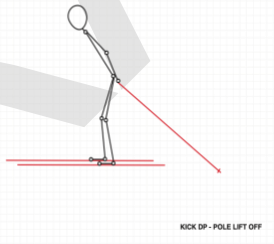
- Classic technique's second gear.
- This technique can very effective at the intermediate speeds.
- Kick double pole requires good grip, so if the conditions are difficult, striding and double pole might be safer sub-technique choices.
- Skiers swing the arms back up in front of the body synchronized with the leg kick
- Power position will be defined as the moment when the poles are in contact with the ground
- Repositioning phase is defined as when the poles are getting back to the next pole plant.
- The kicking leg is creating power during the poles' repositioning phase.

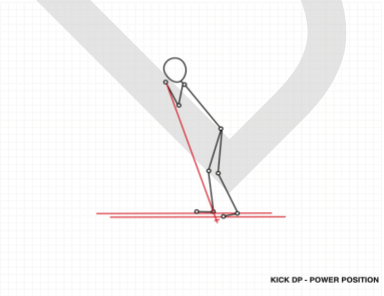


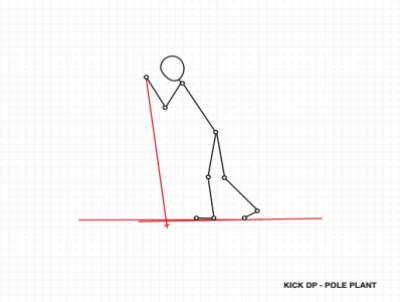



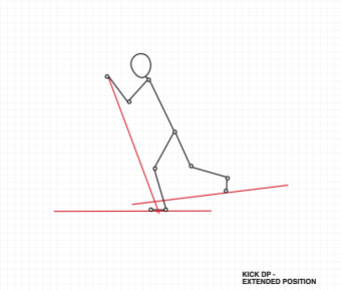



# BODY POSITION

### A - POWER POSITION

- Asynchronous upper and lower body force producing movements, therefore 2 distinct Power Positions
- In power position, keep forefoot pressure on the gliding foot while the arms are working. Because of the kick, the upper body is standing relatively tall so both the legs and the arms get good conditions to create power. This means that the arms will be a bit further away from the body than in a double pole, much like in striding only that in striding the arms work individually.




### B - POWER LINE

Important to keep the nose, knee, and toes aligned and shoulders and hips level. This way all the movements can go straight back and forth, instead of side to side or rotating which results in a loss of power.

### C - LIFT

Always keep the body straight over the gliding foot. Kick must be completed just prior to the weight shifting from forefoot to full foot - this should result in getting a good amount of air underneath the ski at the back, before it pendulums back to the touch down on the next ski. Hips should stay over the midfoot and not get dragged behind the foot with the kick.

# TIMING

### A - POLE PLANT

It is critical that the arms pendulum back in front of the body in time for the poles to swing into a vertical position - the preparation phase. The pole plant initiates after a micro pause at the top of the pole swing to ensure forward hip movement allowing for proper body position. The back leg pendulums forward again

and the poles are planted and starting to move through the power position. Arm position relative to the body is very similar to striding, except they now are parallel like in double pole.

### B - Force Producing Movements (Leg Drive)

As mentioned in the kick double pole intro, this is the only sub technique that the kick (or push for that matter) is coming at the opposite time of when the pole push is. The movement starts approximately when the poles are lifted off the ground. The foot about to kick then gets pushed a tiny bit in front of the other foot. This little preparation movement is to give the foot a split second to have as much body weight on it by the time it is straight under the body when kicking. The kick impulse is short and explosive, before the ski lift happens while the body is still straight over the gliding foot, and then naturally pendulums up in the air.

### C - Follow Through and Reposition Movements

This sub technique stands out because the arms are repositioning as the legs create power, and then the legs reposition as the arms generate power. The important focus to have for the repositioning limbs is to perfectly move back while the working limbs apply power. Arms are actively brought fast forward at the same time as the power impulse from the kick, and the repositioning of the leg timed so it is brought back as the arms/poles are pushing.

# SKATE

- In Skate, there are 4 sub techniques: Offset, One Skate, Two Skate, Free Skate.
- Speed determines the sub technique, and there even are variations within the sub technique.
- The reason skate is a faster alternative than classic is because we can create force pushing us forward with the leg push from a gliding ski, whereas in classic, the ski needs to momentarily stop to get grip when kicking.

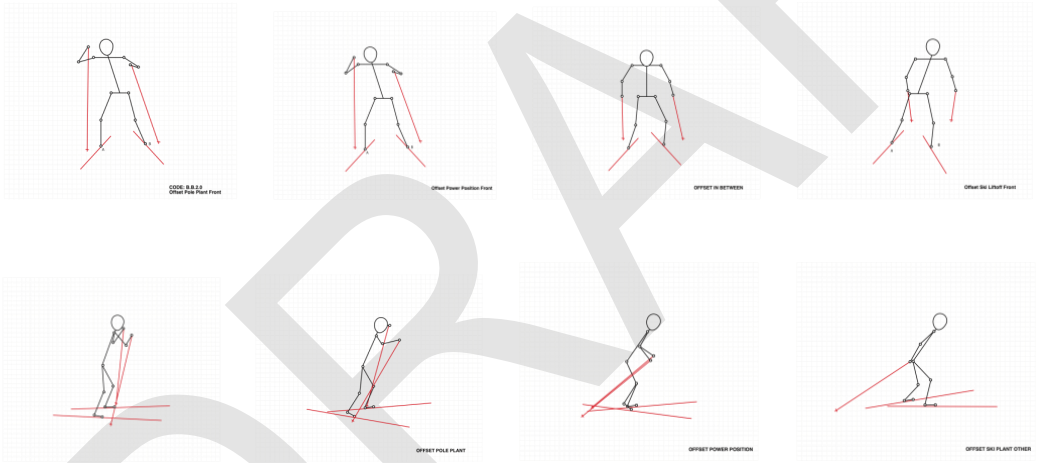
V

- Although it is important to glide on a flat ski during the skate technique, we need to use the edge of the ski to push,which results in a V shape between the skis.
- We adjust the angle of the 'V' according to the ski speed.
- When skiing faster it is possible (and desired) to get an effective leg push from a more acute (smaller) angled 'V'.
- When speed diminishes, the V needs to get bigger.
    - Note that, at the slowest speeds in the offset technique, we seet the best skiers at some point stop making the 'V' angle wider, and instead choose to get an effective push by having a wider opening between the feet.
    - This sets the ski down with the inner edge angled down to push right away, keeping the skis pointing more straight ahead than would be possible with the feet closer to each other.

- As speeds get higher the force producing movements from the pole push becomes more limited in skate.
    - with increased speed the poles are not in contact with the ground long enough to effectively contribute to force generation. and the skiers will be faster by free skating tucking.

## 3.8.4 OFFSET - REGULAR

- The first gear in skate, used at the slowest speeds (usually on steep uphill terrain, it is also an effective technique for accelerations.)
- Offset stands out as a technique because of both timing and position.
- Poling is asymmetric in comparison to one skate as the skier will only pole once per cycle.
- Poling is asymmetric in comparison to two skate as the poling occurs at the same time as the glide ski touches down (three points of simultaneous contact).
- Because of these asymmetries we may observe some resultant rotation of the upper body (to accommodate the pole placement), however it is important to note that the COM is being driven up the hill as straight as possible.
- In the diagram sequence, we see a skier at  pole plant. Leg and arm A are referred to as the dominant side, and leg/arm B the free side. Pole plant and ski put down on the dominant side happens at the exact same time.



### BODY POSITION

#### A - POWER POSITION

- Same angles in the ankle, knee and hips as seen in the other sub techniques
- Key cues to note are: sitting (with the COM too far back), due in part to not having enough flexion at the ankle, or leaning at the waist with straight legs.

#### B - POWER LINE

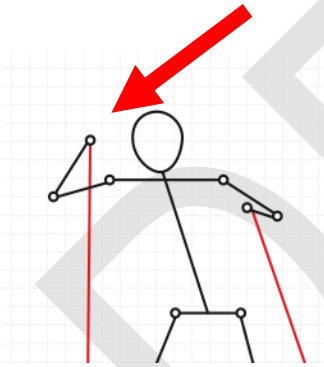
- When speed decreasessignificantly, there is no gliding phase in offset and the skier moves from push to

push. Essentially pushing as soon as the ski makes contact with the snow.

- To accomplish this uninterrupted drive, the skier focuses on moving the  COM up the hill.
- The skis will set on the snow beneath the COMfurther apart to balance between having skis facing the direction of travel and being able to create an angle on the ski to push from.
- To get a good push the skier needs to maintain an effective Power Posiiton and Power Line throughout the cycle.
- To minimize deceleration, there is almost no glide phase during offset.
- To apply force to the ski as rapidly as possible, the power line is on the inside of the ski allowing to push as soon as the ski sets down.

**FORCE PRODUCING MOVEMENTS**

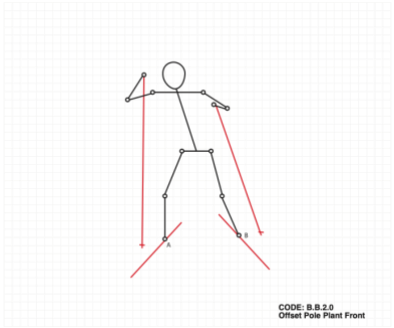
- To maximize force application through the poles, the skier should aim to use the larger muscle groups: Lats, Traps, Pecs, shoulder girdle. This is achieved by keeping the outside elbow at a 90o angle
- Note that the arms/poles are offset at both pole plant and pole lift, with the free side trailing the dominant side.

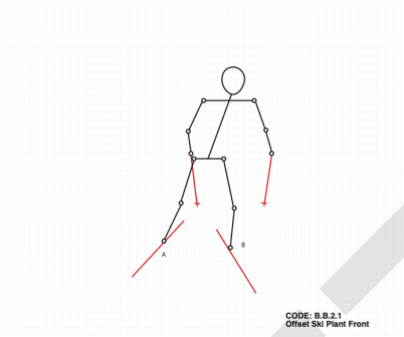


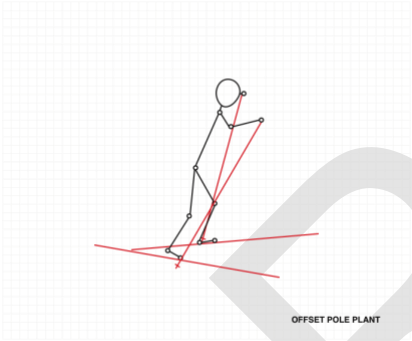
**C - SKI LIFT**

- Vertical displacement of the COM is minimized throughout the cylcleSki lift for each leg should be symmetrical and
- The skier position at ski lift is symmetrical when comparing one side to the other

- At ski lift, the body should form a straight line from ankle to shoulder through the hip to ensures that we are landing on the opposite ski with the COM forward.






## TIMING

### A - POLE PLANT

- The pole plant defines the unique timing for offset, whereby both poles  the dominant ski set down is at the exact same time

### B - FORCE PRODUCING MOVEMENTS (LEG DRIVE)

- Althuogh there is only a pole push on the dominant side skiers push equally from both legs. This means that the rhythm should be the same for both pushes.
- If a skier changes dominant side mid hill this should not be noticeable on the leg pushes, only in the poling

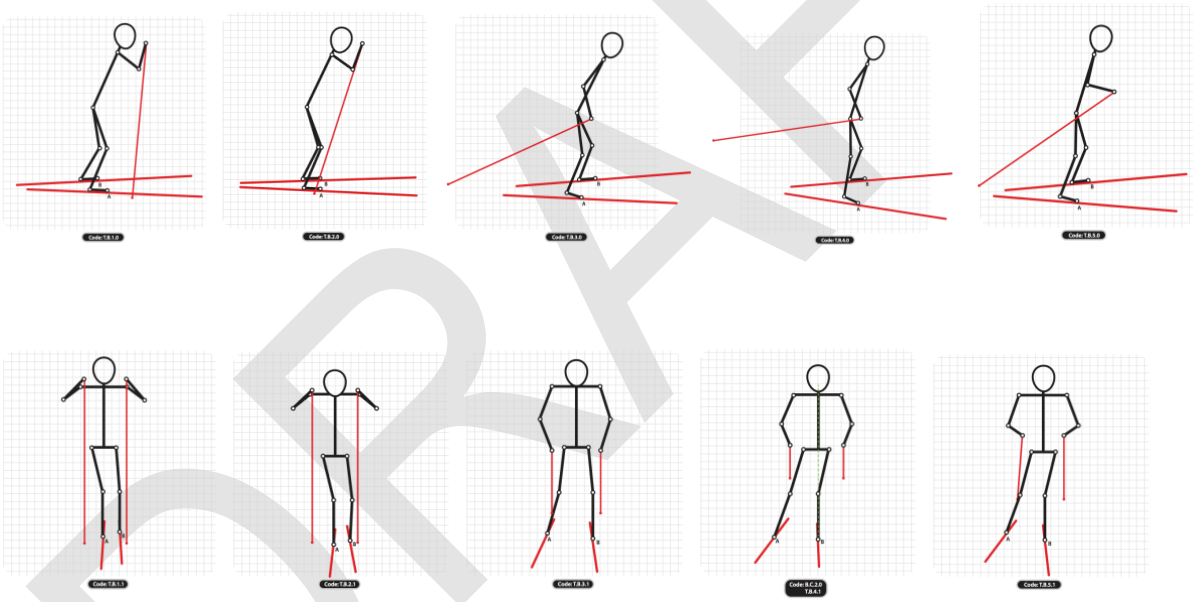
- Skiers should not step up the hill but focus on pushing the COM forward. In so doing, the landing ski will be positioned beneath (and even slightly behind) the COM allowing the skier to immediately drive the new ski.

**C - FOLLOW THROUGH AND REPOSITION MOVEMENTS**

- As the skier pushes on the non-polling side, the arms are lifted and repositioned to be ready for pole plant.
- Because there is minimal glide, the skier must land in a flexed position to immediately drive the leg. Therefore there is minimal to no change in the torso angle to maintain core-hip (JB - Biomechanics) connectivity allowing the poles to be loaded immediately upon contact with the snow.

## 3.8.5 ONE SKATE

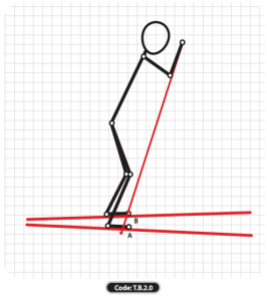
- This is considered second gear in skate and covers a wide range of ski speeds, encompassing relatively slower speeds on inclines, to full sprinting on flat terrain.
- Both tempo and body position can vary from relatively quick tempo resulting in short glide and range of motion (poling and leg drive) ,to slower tempo resulting in longer glide and a greater range of motion (poling and leg drive)
- Note that regardless of ski speed, tempo and range of motion, the starting position is always the same (forward and extended position).

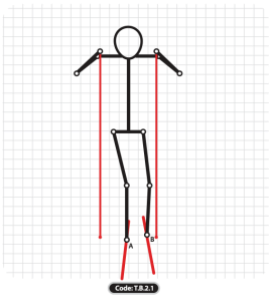


Body position

**A - POWER POSITION**

- The COM (power line) is over the forefoot.
- The angle in the ankle, knee and hip results in the upper body and lower legs being in approximately the same angle relative to the ground



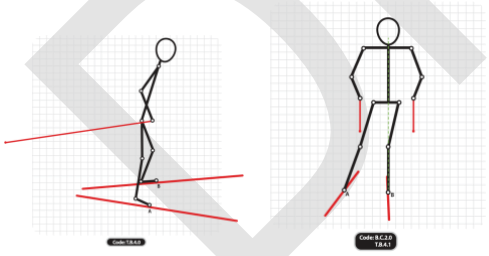


**B - POWER LINE**

- The power line is a vertical line between the nose, knee, and toes at the pole plant.
- The COM is completely over on the glide ski, maintaining the integrity of the powerline in the core throughout the cycle.
- Under acceleration or climbing, the power line shifts onto the inside edge of the ski sooner during the cycle.

**C - LIFT**

- The COM is fully transferred from driving leg to glide leg and force producing movements are over.
- The most frequent mistake here is the weight remaining on the pushing leg too long, resulting in a non-ideal repositioning phase.
- Skiers should be on a single ski as much as possible throughout the cycle



### D – Follow Through and Repositioning Movements

Note that follow through movements begin at the same time, however the ski may still be in contact with the snow for a short period as torso begins repositioning movements.

## Timing

### A - Pole plant

- The skier is on a flat, gliding ski with full weight and balance on the forefront of the gliding foot.
- The pole plant position is similar to the double pole position.
- The pole plant sets the preload of the leg push.

### B - Force Producing Movements (Leg Drive)

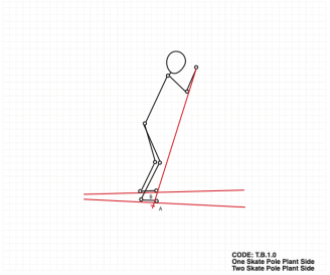
- From the pole plant the skier comes into power position and pushes off with the inner edge of the ski.
- The push from pole and leg is initiated at the same time in the power position once the load phase is over.
- Ski lift occurs at the end of the force producing movements when COM is over the glide ski.

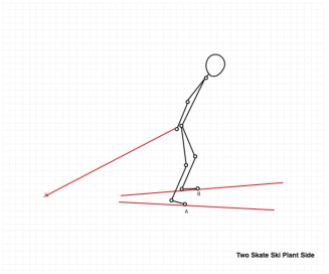
### C – Follow Through and Reposition Movements

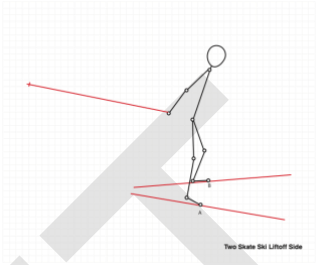
- Follow Through Movements occurs quickly (fast hands) and begins at the pole lift to end of backswing
- Repositioning starts as the body moves forward through sequential joint activation

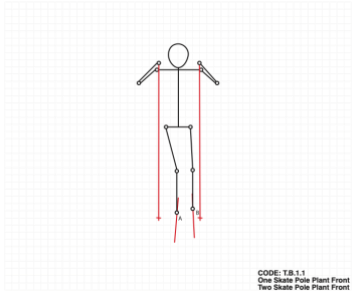
## 3.8.6 TWO SKATE

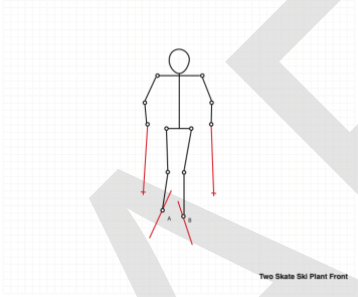
- Third gear, used in easy terrain with high speed.
- Only one pole plant per cycle applying the same movements and timing as for one skate

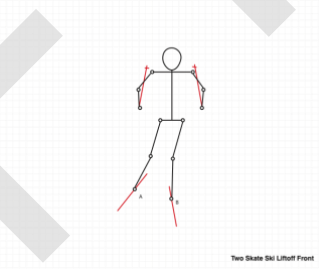



### BODY POSITION

#### A - POWER POSITION

- The COM (power line) is over the forefoot.
- The angle in the ankle, knee and hip results in the upper body and lower legs being in approximately the same angle relative to the ground (on average the upper body has a slightly greater lean forward than the lower legs).

#### B - POWER LINE

- The power line is a vertical line between the nose, knee, and toes at the pole plant.
- The COM is completely over on the glide ski. Maintaining the integrity of the powerline in the core throughout the cycle.
- Due to the high ski speeds, the power line shifts onto the inside edge of the ski sooner during the cycle as compared to one skate

#### C - LIFT

- The COM is fully transferred from driving leg to glide leg and force producing movements are over.

- The most frequent mistake here is the weight remaining on the pushing leg too long, resulting in a non-ideal repositioning phase.

## TIMING

### A - POLE PLANT

- Only one pole plant per cycle, the hands are usually a little further away from the body than in one skate, and pole tips are planted further in front of the boot at pole plant.
- As introduced in "power line" the skier needs to be on a flat, gliding ski with COM and balance on the forefront of the gliding foot.
- The pole plant position is similar to a double pole position.
- The pole plant (catch) sets the preload of the leg push.

### B - FORCE PRODUCING MOVEMENTS (LEG DRIVE)

- ,As there is no repositioning movements on the non-poling side, the skier begins the leg drive from the ski lift positon on the non-poling side.
- On the non-poling side, we can use repositioning movements of the arms to generate greater momentum, similar to how we reposition the arms while kicking in the kick double pole.

### C - FOLLOW THROUGH AND REPOSITION MOVEMENTS

- During the leg drive on the non-poling side, skiers swing the arms back up in front of the body synchronized with the leg kick. (This is the same arm motions that go into jumping from a static position, where you get more power through the body if you use the arm swing).

# 3.9 How to record and fill out Basic technique

## 3.9.1 Video instructions

### Pick the right spots

We recommend finding 3 different spots to do the filming. One for offset and striding, one for one skate and kick double pole, and one for two skate and double pole. The spots should be relatively straight, without any turns in the video area. It should be an open area so it's easy to film from the side with a bit of distance to the track, so the side view shows the entire skier from the side when they pass the camera spot. The length of the area should also be long enough to get at least 10 sec of video. We recommend the offset and striding to be done at 8-12% incline. One skate and kick double pole 4-7%. Two skate and double pole 1-3%. Ideally the same spots can be used both summer and winter.

### Video Quantity

Every sub technique should have one video of the skier from the side and one from the front. In the one from the side try to have some distance from the track so the entire skier can be seen right from the side. In the one from the front try to stand as still as possible, make the skier go straight towards the camera for as long as they can before skiing by just to the side. Every video should at least be 10 sec long to get enough cycles in to see the patterns in the technique. We strongly recommend having at least 60fps footage for better slow-motion view.

### Skier effort

There is not much use in doing these analyzes on super slow Z1 skiing. The skiers should ski at a speed that is representable for a distance race. That means 10/15k race speed for a senior.

## 3.9.2 Analyzing Process

To avoid getting lost in trying to work on everything at the same time, an order of how to grade the skiers has been made. The system is based on an order of what principles to first look at and grade, and what determines when a skier should start focusing on the next step.

| | Technique Category | | | Classic | | | Skate | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Striding | Kick DP | Double Pole | Offset | One Skate | Two Skate |
| BASIC TECHNIQUE | BODY POSITION | A | Power Position | | | | | | |
| | | B | Power Line | | | | | | |
| | | C | Lift | | | | | | |
| | TIMING | A | Pole Plant | | | | | | |
| | | B | FP Movements (Drive) | | | | | | |
| | | C | FT/RP Movements | | | | | | |

There are two main Technique Categories which are further subdivided into subcategories:

**Body Position**

- Power Position
- Power Line
- Ski Lift

**Timing.**

- Pole Plant
- FP/Movements (Drive)
- FT/Reposition Movements

Grading begins in any sub technique by looking at:

- Body Position A: Power Position
- Timing A: Pole Plant

If the score is 3 or better, you can move on to grading B. If the grade is a 1 or 2 the skier does not need to get evaluated on subcategory B or C yet, and should focus on improving subcategory A. Once an skier has achieved a 4 in subcategory A and a 3 in subcategory B, then grading subcategory C can begin.

There are special cases where the skiers can be limited at one of the first stages like A because step B or C is completely off. Then the coach must use best judgment to guide the skiers on a pressing matter. If an instruction is given around the sub technique category C with the intention to optimize step A, then step A is still where the skier is evaluated until grading 3 is achieved.

Below you can see a filled-out example of a Technique Report Card.

## Basic Technique

| | | Technique Category | Classic | | | Skate | | |
|---|---|---|---|---|---|---|---|---|
| | | | Striding | Kick DP | Double poling | Offset | One skate | Two skate |
| Body pos. | A | Power position | 4 | 4 | 5 | 5 | 5 | 4 |
| | B | Power line | 4 | 4 | 4 | 4 | 4 | 4 |
| | C | Ski lift | 3 | 4 | 3 | 4 | 5 | 5 |
| Timing | A | Pole plant | 5 | 4 | 4 | 5 | 4 | 4 |
| | B | Leg kick/push | 3 | 3 | 3 | 4 | 5 | 5 |
| | C | Reposition phase | 3 | 2 | 3 | 4 | 5 | 5 |

## Basic Technique Focus

| | Sub Technique | Tech. Category focus | | Comment |
|---|---|---|---|---|
| Classic | Striding | Body position | C | End contact time with the ground earlier on the kicking ski. More air under the ski at the back while gliding |
| | | Timing | B | Same task as body position |
| | Kick DP | Body position | A | A bit more ankle angle resulting in a more forward pointing knee, and a bit more open hip angle |
| | | Timing | B/C | Syncronize return of the arms to the front and the leg kick. One motion doing both at the same time |
| | Double poling | Body position | C | Finish the poling phase earlier in a taller upper body position |
| | | Timing | C | Finishing earlier, resulting in getting back tall earlier and more time for the preparation phase |
| Skate | Offset | Body position | B | Free leg too far in under you when you set it down - resulting in too long time before the actual leg push starts |
| | | Timing | B | The same as body position. Straight in to push on each side after your foot is set down |
| | One skate | Body position | B | Right ankle needs to be worked on - you sometimes can not hold the line and you end up gliding too far out to the right side |
| | | Timing | A | Your upper body sometimes start moving down from the top position before the arms. Make sure they come down together |
| | Two skate | Body position | A | A little too far forward leaned, and a little too extreme in having your hands over your head before pole plant |
| | | Timing | A | Over all too far back. Two skate is when speed is too high for one skate, you have time to set pole plant further ahead |

## 3.10 How to implement the TRC

### Basic technique

- Film and analyze a minimum 4 times a year, at least once on roller skis and once on snow. However, there is no maximum recommendation, just use coach discretion as to not overload the skier
- We suggest doing classic in a different week then skate to allow for consolidation and refinement

### Basic technique focus

- Technique category focus stay the same until next basic technique update, but comments can be updated as coach and skier see fit

### Rested vs. Fatigued

- Work in a rested state, but also addressed when fatigued. When rested new steps, when fatigued use the skiers own rested state as the reference and standard.

## ACQUISITION OF SKILLS – MOTOR NEURON LEARNING

In order to become technically competent, athletes need to spend time on skis in addition to the structured skill development sessions offered by their club. The more they practice, the sooner they will develop a good skill level!

When recommending additional practice time to the parents of young athletes, however, it is important for coaches to explain that spending time on skis for the purpose of improving technique (repeated practice) is not the same as skiing long distances – the emphasis needs to be on quality rather than quantity. This is often misunderstood, resulting in children skiing kilometer after kilometer, while reinforcing poor technique habits. The latter situation occurs when a skier is unable to retain correct technique because he/she is tired.

The repetition of incorrect technique for long periods of time is exactly what you wish to avoid. Repetition can ingrain a bad habit as well as a good one, and undoing a bad habit is a difficult and time-wasting process.

The following are some points on the acquisition of skills that may be useful in explaining the distinction between repeated practice and simply skiing long distances.

❑ In order for athletes to retain new skills they must ski more than once a week; to significantly improve their skills they must spend time on skis several times a week.

❑ Individuals improve their performance and attain an expert level not as an automatic consequence of more experience with an activity, but rather through structured learning and purposeful adaptation.

❑ The effects of extended and deliberate practice are more far-reaching than is commonly believed. Deliberate practice can also lead to anatomical changes resulting from adaptations to intense physical activity.

❑ If skiers have practiced their sport incorrectly, it becomes more difficult to change and adapt (later), and then they cannot move on to further improve technique execution. It is essential that they are taught the right methods from the beginning and that these methods are accurately replicated and reinforced in practice.

❑ Will require greater cognitive focus by the skier initially, then becomes habit requiring less "thinking".

❑ Be mindful of paralysis by analysis. If you give your skier too much to think about at one time, the skier may lose the feel for the technique.

❑ **Practice doesn't make perfect – practice makes permanent. Only perfect practice makes perfect permanently.**

## CONCLUSION

**To Coaches:** Involve the skier in the process of using the TRC. To what extent is based on the best judgment of the coach, but the skier should be involved in their report card and understand their strengths and gaps with the terminology from this manual.

**To Skiers:** Be innovative and a pioneer. Skiers create what the best technique is, not coaches. The coach has an important role when it comes to seeing changes in technique among the best and being able to communicate suggestions to improvements for an skier and being an objective set of eyes. However, it is the skiers that are developing what the most effective technique is. Take Klæbo and his "running" technique in striding. A couple of years ago no one did this. Now you see anyone from kids to most world cup skiers testing and using the technique themselves. So, learn from the content in this document, it is a strong way to establish elite level technique, but know that testing new things, and being creative about details is what brings the next level in technique.