Mini project content:

- Provide an overview of how different kinds of technology have contributed to developments in sports both from a perspective of optimizing performance and from an injury prevention perspective.
- Identify disciplines for which you will predict that further technological development will significantly contribute to improvements of performance in near future.
Authors

- M. Supej, 2010 Mechanical parameters as predictors of performance in alpine World Cup slalom racing.
- E. Müller, 2003 Biomechanical aspects of new techniques in alpine skiing and skijumping.
- N. St-Onge, 2004 Effect of ski binding parameters on knee Biomechanics.
- T. Yoneyama, 2009 A ski robot for qualitative modelling of the carved turn.
History of measurement technique

- Three phases where recognized in literature.
  1. Phase was the attention on qualitative skiing performance starting from early 1930’s going on.
  2. Phase was quantitative studies of motion processes in skiing. Möser (1957) developed dynamograph in the form of ski-mounted mechanical lever-gear to register GRF from a strip of paper.
  3. Phase begin in 1980’s with key variables measured using biomechanical methods. For quality of technique in skiing, and to provide information about factors that may cause typical skiing injuries.
Introduction to parallel skiing

Alberto Tomba - Calgary 88 - 2a Manche Slalom Gigante Gattai parallel.mp4
Introduction to carving skiing

Svindal - Alpine Skiing - Men’s Downhill - Vancouver 2010 Winter Olympic Games.mp4
without any lateral skid component. The navigable curve radius during carved turns is a function of the following variables: ski waist, on-edge angle and ski flexion (Fig. 1). The more strongly waisted the ski and the greater the on-edge angle, the more strongly the ski must flex to maintain contact with the slope along the total length of the edge. The curve cut into the snow under full contact with the slope is designated the turn radius. Figure 2 shows the ideal cut curve radius as a
Method (Müller)

- Qualitative measurement of testskiers making 6 runs with either carving ski $r = 14$ m or parallel ski $r = 32$ m.
- Ground reactions force from sole inserts (2 plates)
- Three dimensional filming
Biomechanic analyse

Parallel skiing

Carving skiing

Outskii working hard

Fig. 3. Ground reaction forces and knee angles during two turns with the traditional parallel technique (mean values of six runs). Reproduced with permission from Schiefermüller et al. (in press).

Fig. 4. Ground reaction forces and knee angles during two turns with the carving technique (mean values of six runs). Reproduced with permission from Schiefermüller et al. (in press).
Mechanical parameters as predictors of performance in alpine World Cup slalom racing.

(Supej)

1: To develop a method for classifying slalom skiing (Carving) performance and to examine differences in mechanical parameters.

2: To examine whether the
- CM’s velocity (v)
- Center of mass’s acceleration (a)
- CM’s turn radii (R_CM)
- The arithmetic mean of ski’s turn radii (R_AMS) i.e. the length of the curve.
- GRF
- Diff(e_mech) can be used as predictors of performance.

3: To investigate relationships among these
Fig. 1. Schema of the camcorders setup.
Calculations to alpine performance

- One other text implies a generalized friction parameter.
- And the other parameter is defined as the differential specific mechanical energy

C1. Specific mechanical energy $e_{\text{mech}} = v^2/2 + gz$, where $v$ represents the absolute velocity of the skier’s center of mass, $z$ the altitude and $g$ gravity.

C2. Differential specific mechanical energy describing the quality of skiing $\text{diff}(e_{\text{mech}}) = -\Delta(v^2/2)/\Delta z - g$, where $\Delta$ represents the differential. A more detailed explanation regarding C1 and C2 can be found elsewhere (Supej, 2008).

C3. Turn radii were calculated by fitting an arc segment on each set of three neighboring points on the center of mass’s ($R_{\text{CM}}$) and on the arithmetic mean of the skis’ trajectory ($R_{\text{AMS}}$). The arithmetic mean of the skis’ trajectory was derived from the arithmetic mean of the ankle joints at each point of observation.

C4. Newton’s second law was used to estimate GRF. This was calculated as the sum of the acceleration vector multiplied by the mass of the skier and the static component of the gravity force. The GRF is presented in multiples of body weight (BW).

C5. The skier’s acceleration ($a$) is calculated from the skier’s absolute velocity ($v$) using linear approximation and a third order zero-lag Butterworth filter with a cut-off frequency of 6 Hz.
Table 1. Mechanical parameters calculated at the first and at the last recorded gate for skiers from higher performance (HP) and lower performance (LP) groups.

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<th>Rank</th>
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<th>$\Delta e_{mech}$ (J/kg)</th>
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<th>$v_{out}$ (m/s)</th>
<th>$v_{out} - v_{in}$ (m/s)</th>
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The skiers are ranked by the $\Delta e_{mech}/v_{in}$ values.

* $P < 0.05$; ** $P < 0.01$; a trend was marked with * $P = 0.054$.

By definition, the skier decreases absolute velocity $v$ when $\text{diff}(e_{mech}) < -9.81 \text{J/kg/m}$ and vice versa.
The findings

The main findings were: (1) a new performance classification parameter $\Delta e_{\text{mech}}/v_{\text{in}}$ for short sections of the alpine race course was developed and found to be decisive and pertinent, (2) $v$ and $\text{diff}(e_{\text{mech}})$ were shown to be significantly different between the HP and LP groups, while there was no significant difference in $R_{\text{CM}}$, $R_{\text{AMS}}$, $a$ and GRF, (3a) a positive relationship between turn radii and $\text{diff}(e_{\text{mech}})$ was demonstrated, (3b) a “hysteresis” and a phase transition was observed in GRF/$R_{\text{AMS}}$ relationship at 15 m radii, (3c) the highest GRFs were related to higher energy dissipation and (3d) $a$ was inversely proportional to GRF.

The new parameter, $\Delta e_{\text{mech}}/v_{\text{in}}$, includes entrance velocity and entrance altitude as well as exit velocity and exit altitude, information, which cannot be obtained with conventional time measurements.

section. However, despite the more profound mechanical basis for $\Delta e_{\text{mech}}/v_{\text{in}}$ compared with the section time and previous strengths, the two parameters have some common weaknesses; they do not encompass the entrance and exit: (1) orientation of the skier and (2) position left–right according to the virtual planes (photocell beams) constructed at the entrance and exit of the section. It is also

the entrance and exit of the section. It is also important to stress that $\Delta e_{\text{mech}}/v_{\text{in}}$ is not intended for use when analyzing long sections in alpine skiing, given that a mistake at the beginning of a section might not influence the $v_{\text{out}}$ and thus $\Delta e_{\text{mech}}/v_{\text{in}}$. On
Interesting findings

- High $V_{in}$ made a higher negative acceleration.
- Maybe there would be a velocity barrier above which they made mistakes, or in other words, the skiers needed to control velocity to avoid mistakes.
- The shortest $R_{AMS}$ associated with the highest energy loss.
- It is preferable to reduce the presence of the highest GRF i.e. the shortest turn radii.

The phase transition in the GRF/$R_{AMS}$ relationship [Fig. 4(a)] and the fact that the GRFs were always lower than 1 BW at $R_{AMS} > 15$ m indicated that the skiers had to use skis with a sidecut radius of $\sim 15$ m. These results are supported by the model's outputs, where GRFs above 1 BW are not possible when skiing radii are longer than the skis' sidecut radius.
China!! (Yoneyama)
Forces in a carving turn

Gravity force in the falling direction

$mg \cdot \sin \alpha$

Reacting force from the slope surface in the slope plane

Centrifugal force

$m \frac{v^2}{R}$

Turn Radius

Turning velocity $v$

Slope angle $\alpha$

Reacting force from the slope surface in the slope plane

Gravity force in the falling direction

$mg \cdot \sin \alpha$
tried experimentally, skidding of the ski has been observed. As observed above, (1) the artificial running surface used was unfortunately rather different from snow for the case of radial (outward) forces, and (2) the robot has a much lower power-to-weight ratio than a human being. These parameters need to be altered to allow a more accurate simulation of human skiing.
5.2 Significance of the robot experiments

The robot is still under development and much remains to be done. However, it is still able to tell us something about the real effect of each of the joint motions and other factors of the ski turn, at least in a qualitative sense.

The robot has allowed the effects of each of the joint motions to be separated. Abduction–adduction and flexion–extension motions have been found to be effective because they directly change the edge angle of the ski. By emulating the detailed joint angles of a skilled athlete, the skiing performance of the robot was improved. A series of leg angle changes to point the waist inward during the turn, modelled on the human expert, was found to be particularly effective. Load sharing between the skis was improved and the downhill force increased in the first half of each turn. This approach will be extended in the future by applying observations from the measurement of more athletes.
The ski robot was quite different from a human being, limiting its usefulness as a model. The main issues were the non-human ratio of mass centre height to ski separation distance, the ratio of the power of the motors to the mass, and turning speed with the frictional properties of the non-snow slope surface. These need to be addressed in future developments.

Fig. 13 An example of the measured foot load of the top athlete Mr. Hirasawa during a turn sequence
Injury prevention (N. St-Onge)

- Altered ski binding

Aim of the study: Evaluate the effect of the position of the binding pivot point and binding release characteristics on ACL strain during phantom-foot fall.
Skader i lavere ekstremiteter er faldet meget de sidste 20 år hvor i 1970’erne de stod til omkring 40-60% af alle skader.

Tibia and ankle injuries er faldet med omkring 70-90%.


ACL 3. grad sprain ligger på 18,4% af alle ski skader.
related injuries. In fact, it is widely recognized that the decrease in the rate of lower-extremity injuries may be due to improvements in ski-boot-binding systems. For example, taller and stiffer boots give greater protection to the foot and ankle. Also, bindings, which are more effective in terms of releasing capability, offer better protection against tibial fractures caused by bending and twisting mechanisms.

In the present study, we developed a biomechanical computer knee model to study ACL strain during a ski injury mechanism. We chose to reproduce the phantom-foot injury mechanism with our model because it is one of the most common mechanisms of ACL injury in downhill skiing and is also generated by a twist load. The main goal of the present study was to evaluate the effect of the position of the pivot point on ACL strain and thus on the chances of tearing the ligament. The second goal was to evaluate the effect of binding release characteristics on ACL strain.
FIGURE 8—Effect of pivot point position on maximal ACL strain. A 600-N load was applied at the projection of the tibial axis as well as 150, 300, or 450 mm behind that point. The pivot was positioned 63 mm in front (white bar), 63 mm in the back (gray bar), or 135 mm in the back (black bar) relative to the center of the boot.
Results

- A binding with fast-release characteristics with a pivot positioned in front of the center of the boot produces less strain on the ACL.
- A pivot positioned at the back of the binding is more effective for sensing loads that occur at the tip of the ski.
- However, it is less effective for sensing loads that occur at the tail of the ski and, therefore, offers less protection during a phantom-foot fall.
- A binding with pivot at both ends of binding could sense loads from both ends of ski, and protect against high loads.
Limitations

- Snow conditions, muscle activation, detailed characteristics of binding.
Injury rates

Current injury rate in Scotland (2009/10 season) - 2.38 injuries per 1000 skier days (419 MDBI)

Since ski injury studies were first reported in the 1970's, the overall rate of alpine ski injuries has decreased by about 50%. It now stands at around 2 injuries per thousand skier days - lower than most people think. This rate has been stable (or even in some countries continuing to decrease slowly) for the last ten years or so. The decrease in the overall injury rate is most likely linked to advances in alpine equipment (carving skis being one example) as well as improvements in ski area management (grooming, slope design, signage, barriers etc). The biggest decrease has been in lower limb fractures, consequent on the introduction of release binding systems and plastic-shelled alpine boots.