SCIENCE AND SKIING V

Edited by

Erich Müller
Stefan Lindinger
Thomas Stöggl

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Introduction

The Fifth International Congress on Science and Skiing was held at St. Christoph a. A., Tyrol, Austria. It was the follow up conference of three International Congresses on Skiing and Science, which were also held in St. Christoph a. A., Austria, in January 1996, in January 2000 and in December 2007 and of the International Congress on Science and Skiing, which was held in Aspen, Colorado, USA, in April 2004.

The conference was organized and hosted by the Department of Sport Science at the University os Salzburg, Austria, and by the Christian Doppler Laboratory "Biomechanics in Skiing", Salzburg, Austria. It was also again part of the programmes of the steering group "Science in Skiing" of the World Commission of Sports Science.

The scientific programme offered a broad spectrum of current research work in Alpine and Nordic skiing and in snowboarding. The highlights of the congress were five keynote lectures. The scientific programme of the congress was completed by 2 work shops, 99 oral presentations and 66 poster presentations.

In the proceedings of this congress, three keynote lectures as well as most of the oral presentations are published. The manuscripts were subject to peer review and editorial judgement prior to acceptance.

We hope that these congress proceedings will again stimulate many of our colleagues throughout the world to enhance research in the field of skiing so that at the Sixth International Congress on Science and Skiing, which will be organized in the winter 2013/14, many new research projects will be presented.

Erich Müller
Stefan Lindinger
Thomas Stöggl

We would like to thank Elke Lindenhofer for the time and the enthusiasm she invested in the editing of this book.

Part One

Keynote Papers

Can a ban on doping in skiing be morally justified?

Loland S.

1 Introduction

As most other sports, skiing has had its doping cases with athletes using banned performance-enhancing means and methods. Cross country skiing has been particularly exposed, probably due to extensive possibilities of biomedical manipulation of a key quality in performance: endurance.

During the last two decades and with the 1999 establishment of the World Anti-doping Agency (WADA) as a decisive step, the struggle against doping has intensified and involves not just sport but also public authorities and governments. The struggle however is not without challenges. For instance, to draw the line between acceptable and non-acceptable performance-enhancing means and methods is a complex scientific and moral enterprise. Actually some scholars hold that the ban on doping in sport is problematic and even unjustifiable (Black & Pape 1997; Brown 1991; Tamburrini 2000; Savulescu et al 2004). And, as is evident from extensive doping cases, some athletes and coaches seem to accept and indeed practice doping (Waddington and Smith 2009).

What then are the core reasons to categorize and ban certain performance-enhancing means and methods as doping? With examples from skiing I will examine whether anti-doping can be properly justified from a moral point of view.

2 Methods

The approach is one of practical, normative ethics. I present a systematic and principled argument in which ethical dilemmas are examined on the background of relevant facts and examples. The approach is inspired by the methodology of reflective equilibrium as developed by John Rawls (1971). First, I will sketch how intuitively appealing arguments in support of the ban need modification. Second, I will propose a justification of a ban in which traditional and new arguments are combined in a systematic way.

Traditional arguments: fairness and health

A frequently used argument in support of anti-doping is that doping is unfair. The underlying understanding of fairness seems to be a neo-Kantian one: Fairness is a moral obligation on rule adherence that arises when we are voluntarily engaged in rule-governed practices (Rawls 1971). Skiers using EPO or anabolic androgenic steroids (AAS) break the rules to get an exclusive advantage. For doping to be efficient, dopers depend upon the rule adherence of others. In this way dopers enjoy the benefits of the cooperation of others without doing their fair share. They are free riders of the sports system and treat other competitors as means only in the striving towards their own success. Skiers who are not caught get away with a rule violation and an exclusive and unfair advantage. They cheat.

The fairness argument however does not really help in the justification of the doping ban itself. We cannot justify a rule by reference to the wrongness of breaking it. What is at stake here is the very *rationale* for banning doping in sport. In fact, the fairness argument is sometimes used to support lifting the doping ban (Tamburrini 2000). If a significant number of skiers break the rules without being caught, a minority of rule-abiding skiers has a disadvantage. Morality does not pay. The situation is unjust and the obligation of fairness becomes problematic. To restore justice, an alternative could be to make all kinds of performance-enhancing means and methods open to all.

Stronger arguments in favor of anti-doping can be found in the view of doping as a health hazard and as implying a significant risk of harm. Although solid scientific evidence might be lacking in some cases, there are strong indications that extensive use of EPO and AAS implies serious health risks and even the risk of death.

The problem with this argument is that practicing elite sport in general involves significant risks of harm. Long-term and hard training implies a constant balancing of the anabolic and catabolic processes of the body. Imbalances can result in overtraining and injuries. Similarly, the intensity of competition can lead to acute injury. In events such as ski jumping and downhill skiing, the taking and calculation of risk can be considered part of the skill test. There is always the possibility for serious harm. An argument on banning doping due to health risks could be developed into a more general argument on banning elite skiing and elite sport as a whole.

This conclusion is unreasonable however as no distinctions are made on the relevance of health risks as related to the values of sport. Health is not the primary value in all circumstances. Risks of harm must be weighed against other values. Athletes take their chances in training and competition. In elite skiing there is a strong drive to improve, to realize athletic potential, to test the potential of talent. The challenge of the training process is to strike the optimal balance between anabolic and catabolic processes. The challenge of competing is to put in the necessary effort to succeed and at the same time be smart and avoid injuries. One of the important challenges in ski jumping and downhill skiing is the proper calculation and taking of risk. Health risks linked to doping seem to be of a different kind. Why?

The nature of athletic performance

An idea often expressed by sport leaders and athletes is that drug-enhanced performance comes about without training and individual effort. The enhancement is somehow ‘undeserved’. Doping is considered ‘unnatural’ and ‘artificial’, and the risk involved, therefore, is considered unnecessary and non-relevant.

The problem is that ideas of the ‘natural’ and the ‘artificial’ are to a large extent social and cultural constructions that change over time.

There are countless examples of what was considered ‘unnatural’ yesterday has become common practice today. During most of the 20th century there was a strong resistance against women’s sports as ‘against nature’ (Guttmann 1991). At least in the Nordic countries, the introduction in the 1970s of weight training among cross-country skiers resulted in strong protests as such training was considered ‘artificial’ and against the ideals of the sport (Bomann-Larsen, 1993).

The idea of drug-enhanced performance as contradictory to sport values and somehow undeserved indicates that the question of anti-doping goes straight to the heart of discourses of the meaning and value of sport. A moral stand point towards doping needs to build on interpretations of what sport or more precisely what athletic performances are all about.

An athletic performance is the complex product of a high number of genetic and non- genetic influences from the moment of conception to the moment of performance. As with all human phenotypes, a clear-cut distinction between genetic and environmental factors is impossible. For analytic purposes however the distinction makes sense (Loland 2002).

Genetic factors refer to the predispositions for developing relevant phenotypes for good performances in a sport. A person with good predispositions is usually characterized as a ‘talent’. Cross-country skiing talents are predisposed for developing endurance. Alpine skiing talents are predisposed for developing fine tuned motor action and strength. Talent in this sense is distributed in the so-called natural lottery and based on chance.

Athletes develop talent through gene–gene–environment interaction. These are influences from the very first nurture via development of general abilities and skills, to specific training and the learning of the particular techniques and tactics of a sport. Environmental influences are based in part on chance and luck. Successful skiers have favorable genetic predispositions and are often raised close to a skiing resort with good coaches and instructors. No elite performance however comes about without own strong effort.

Athletes realize their talent through hard training over many years. Competitive sport is primarily meritocratic in kind.

The critical question is whether all kinds of inequalities linked to performance (including those caused by performance-enhancing drugs) are of relevance in skiing, or whether some inequalities ought to be eliminated or compensated for. In what follows, and based on previous work (Loland 2001, 2009), I will critically review two main positions in this respect.

The thin interpretation

From the perspective of the thin interpretation of athletic performance, 'anything goes'. Within the competition itself there are rules to be kept such as those against hands in soccer, or kicking in handball, or using violence against other athletes in cross-country skiing events. These are constitutive rules that make up the sport. Without constitutive rules athletic performances cannot be evaluated at all.

Restrictions on performance enhancement outside of competitions, however, for instance in the form of amateur rules or the current ban on drugs, are considered irrelevant. In the thin interpretation sport is seen to be about the maximization of human performance potential with whatever means athletes find appropriate. The view is often linked to anti-paternalistic conceptualizations of autonomy and individual freedom and responsibility (Tamburrini 2000).

On the critical side thin interpretations can be seen as sociologically naive and contra-productive (Loland, 2001). No athlete is an island with full freedom to choose but a part of complex social networks and power relations. Without out-of-competition regulations, athletes easily become even more dependent upon external expertise than what is the situation today. The control over and responsibility for performance is moved gradually from athletes and teams towards external expert systems. According to critics, this goes against the idea of athletes as free and responsible moral agents and puts athletes in a vulnerable position. Elite skiing might turn into something like grand scientific experiments of human performance with athletes as the guinea pigs. Sport loses its value as an admirable sphere for the cultivation of human talent.

The thick interpretation

The alternative is a thick interpretation in which a similar concern for athlete autonomy, freedom and responsibility leads to further regulations. Inequalities in genetic predispositions for performance based on chance are not just or unjust in themselves. Ethical problems can arise however by the way these inequalities are interpreted and understood in human practice. A general principle integrated in many moral theories, ‘the fair opportunity principle’ (FOP), goes as follows:

Persons should not be treated unequally based on inequalities that they cannot influence or control in any significant way and for which they therefore cannot be claimed responsible.

In democratic societies, the distribution of basic goods and burdens are built upon this principle to a large extent. For example, physical and mental handicaps or other unfortunate conditions in life for which individuals cannot be held responsible are compensated for by financial support and integrative efforts in work and leisure.

FOP seems to have implications in sport and for the doping discussion as well (Loland 2009). The rule systems of sport include many attempts to eliminate or at least compensate for a series of inequalities with impact on performance but upon which the individual has little influence or control. Athletes are classified according to sex, age, and sometimes body size. In skiing events female athletes do not compete with male athletes, as there seems to be significant inequalities in genetic predispositions for strength and endurance to the advantage of men. Mixed competitions seem unfair. Sport seems to cultivate inequalities upon which individuals can have impact and influence, in particular by own efforts. Sport rewards individual and team effort, merit and responsibility. Murray (2007) proposes a normative ideal of sport as being about the *admirable* development of natural talents. From the thick interpretation perspective, athletic performances are admired as strong expressions of human perfectionism *[There is of course much room for improvement of fair opportunity in sport. In some sports, there is a need for more classification, other sports seem to classify too much. For instance, in basketball and volleyball where body height is crucially important, there is a rationale for classification according to height. In ski jumping, biological sex may be irrelevant to performance, and perhaps sex classification can be abandoned. Current inequalities in performance are due to socialization and a lower emphasis on female ski jumping, not biology. Moreover, a systematic application of FOP would have radical consequences for the regulation of inequalities in financial, scientific, and technological resources. In skiing one possibility would be to increase the standardization of skis bases and ski preparation. Today inequalities in ski quality are of decisive impact to competitive outcomes. This discussion however belongs to a more extensive debate about fairness in sport that is beyond the scope of this short essay.].*

Doping revisited

Let me now return to the case of doping. Whereas a thin interpretation implies rejection of regulations of performance-enhancing means and methods outside of competition, thick interpretation implications are different. Drugs are biochemical substances with ergogenic effects such as EPO, or anabolic effects such as AAS. Some substances are agonists. They mimic the action of substances that occur naturally in the body. Others have antagonist effects. They are not produced by the body and prevent biochemical agents produced in the body to interact with their receptors (beta-blockers). In general, it can be said that drugs interact with their biological targets and lead to changes in the biochemical systems of the body.

To a certain extent it makes sense, then, to say that doping enhances performance independent of talent and without individual athletic effort. Inequalities due to doping are not the results of chance or luck, neither are they expressions of athletic merit. Performance-enhancing effects of drugs therefore can be considered non-relevant to sport. To legalize doping would decrease athletes' responsibility for their performances, often in favor of an external expert system, and hence to reduce athletes' potential of acting as free and responsible moral agents. The potential for sport as a sphere of admirable human perfectionism would decrease. From the thick interpretation perspective, the use of performance-enhancing drugs implies unnecessary and non-relevant health risks and should be banned.

Based on this premise the fairness argument becomes valid, too. The ban on drugs is justified without reference to the wrongness of breaking it. Dopers violate the rules to get an exclusive advantage. For their drug use to be efficient they rely upon the rule adherence of others without doing their fair share. They cheat and therefore doping is unfair. If the situation is unjust in the sense that several dopers are not caught and get away with an unfair advantage, the problem is not the doping ban but the weakness of the control system.

3 Concluding comments

I have argued that the doping issue goes straight to the heart of questions of the value and meaning of sport. Justification of anti-doping cannot be based on fairness and health arguments alone but ultimately on a normative view of sport. In my view the thick interpretation of athletic performance is the stronger one in this respect.

The proposed justification of anti-doping does by no means solve all problems in the field. There are a series of practical, financial and judicial challenges that have not been addressed here. Moreover, a ban will always meet the challenges of distinguishing between acceptable and non-acceptable performance-enhancing means and methods. The doping field is loaded with gray areas and there is need for systematic and good casuistry to navigate in informed and reasonable ways. This implies walking back and forth between general principles and the particularities of the means or methods under consideration.

The anti-doping movement puts an emphasis on the development of facts and tests. This paper demonstrates that a justification of anti-doping necessarily has to build on a normative view of sport. It is an attempt, then, to strengthen the normative premises of anti-doping which again may facilitate even better casuistry and reasoning schemes in the future.

Note:

This text is a slightly adapted version of Loland, S.: Can the Ban on Doping in Sport be Morally Justified? in Savulescu, J.; ter Meulen, R. and Kahane, G. (eds.) (2011): Enhancing Human Capacities. Oxford: Wiley-Blackwell, pp. 326-331.

References

Black, T. & Pape, A. (1997). The Ban on Drugs in Sport: The Solution or the Problem? Journal of Sport and Social Issues, 21 (1), 83–92.

Bomann-Larsen, T. (1993). Den evige sne – en skihistorie om Norge. Oslo: Cappelen.

Brown, M.L. (1990). Practices and Prudence. Journal of the Philosophy of Sport, 17, 71–84.

Guttmann, A. (1991). Womens Sport: A History. New York: Columbia University Press.

Loland, S. (2001). Technology in sport: Three ideal-typical views and their implications. European Journal of Sport Science, 2(1), 1–10.

Loland, S. (2002). Fair Play in Sport. A Moral Norm System. London: Routledge.

Loland, S. (2009). Fairness in Sport: An Ideal and its Consequences. I Murray, T. H; Maschke, K. J. and Wasunna, A. A. (eds.). Performance-Enhancing Technologies in Sports. Ethical, Conceptual, and Scientific Issues. Baltimore: The Johns Hopkins University Press, s. 160-174.

Murray, Thomas H. (2007). Enhancement. In Steinbock, B. (2007) The Oxford Handbook of Bioethics. Oxford: Oxford UP, 491-515.

Rawls, J. (1971). A Theory of Justice. Cambridge, MA: Harvard University Press.

Savulescu, J., Foddy, B. and Clayton, M. (2004) Why We Should Allow Performance-enhancing Drugs in Sport. British Journal of Sport Medicine 38 (2004), 666-670.

Tamburrini, C. (2000). 'The Hand of God'. Essays in the Philosophy of Sport. Gothenburg: Acta Universitatis Gothoburgensis.

Waddington, I. and Smith, A. (2009). Addicted to Winning? An Introduction to Drugs in Sport. London: Routledge.

Challenges and issues in ski jumping biomechanics

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1 Introduction

Ski jumping is very specific and unique. One important aspect is that ski jumping is almost exclusively performed as a competitive sport. It needs spacious and expensive facilities (including jumping hill, chair-lift, judges' tower etc.) as well as very high and specific organizational demands. Depending on the hill size the performance time only lasts between 6 and 12 seconds. The competition consists of two runs only. In a common session of hill training around six trials are performed leading to a ratio between 'performance time' and 'rest time' of about 1:120. These circumstances make high quality training regimes, including dry-land training in terms of conditioning and specific coordination training, necessary. Additionally, research on biomechanics, motor control and training theory can provide a substantial support for accordingly improving the quality of training and the performance in ski jumping. A substantial number of studies regarding biomechanical issues of ski-jumping have already been published. The papers primarily deal with aspects related to performance enhancement, limiting factors of the take-off, specific hill and dry-land training and conditioning, aerodynamics and safety. The methodologies used in the corresponding experimentally oriented papers are kinematics, ground reaction force (GRF) analyses, electromyography, wind tunnel measurements and computer simulation. The research covers both competition and training in hill jumps and dry-land training in imitated take-offs (Fig. 1; Schwameder, 2008; 2009).

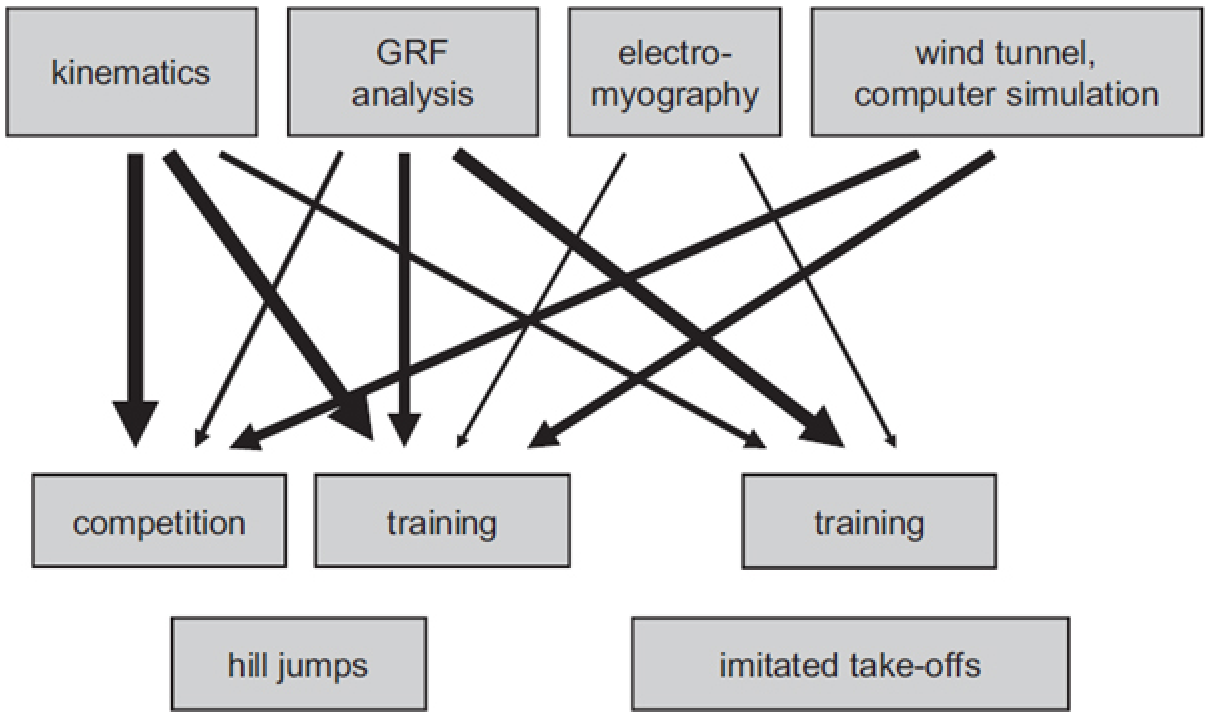

Fig. 1: *Biomechanical research papers on ski jumping. The thickness of the arrows present the number of publications with respect to methodology and research situation (hill jumps, imitated take-offs, training).*

2 Experimental research, biomechanical methodology and selected results

Experimental biomechanical research can be performed on different levels. This is schematically presented in the 'pyramid' in Fig. 2. The basis is built by the detection and analysis of singular physical components. In ski jumping this could be the determination of the maximal force or the rate of force development of the knee extensors. The next higher level is the analysis of singular coordination components. General jumping tasks could be appropriate representatives for this category in ski jumping. This is followed by very specific exercises mimicking the 'real' performance tasks. This is better known as imitation exercises. They are commonly used if the number of performing real competitive motor tasks is restricted or if specific components of 'real' tasks should be pronounced. In ski jumping imitation exercises are widely used in coordination and conditioning training. Chapter 3 will provide more detailed information on this. The following level is the analysis of competitive motor tasks under training conditions. In this case still measurement devices can be used which would not be allowed during competitions. The top of this pyramid is built by the research during competitions. In ski jumping video technique and force plates implemented into the take-off table are examples for measurement methodology usable during competitions.

The different levels of research area presented here also show various quality of internal and external validity moving generally in opposite directions. The highest external validity only can be achieved in measurements during competition. At any lower level the external validity is reduced as only parts of the competition exercises or only singular coordinative or physical components are investigated. On the other hand, the latter can be much better controlled leading to a high level of internal validity. As on higher levels of the pyramid the research conditions cannot be sufficiently controlled, internal validity can be substantially reduced.

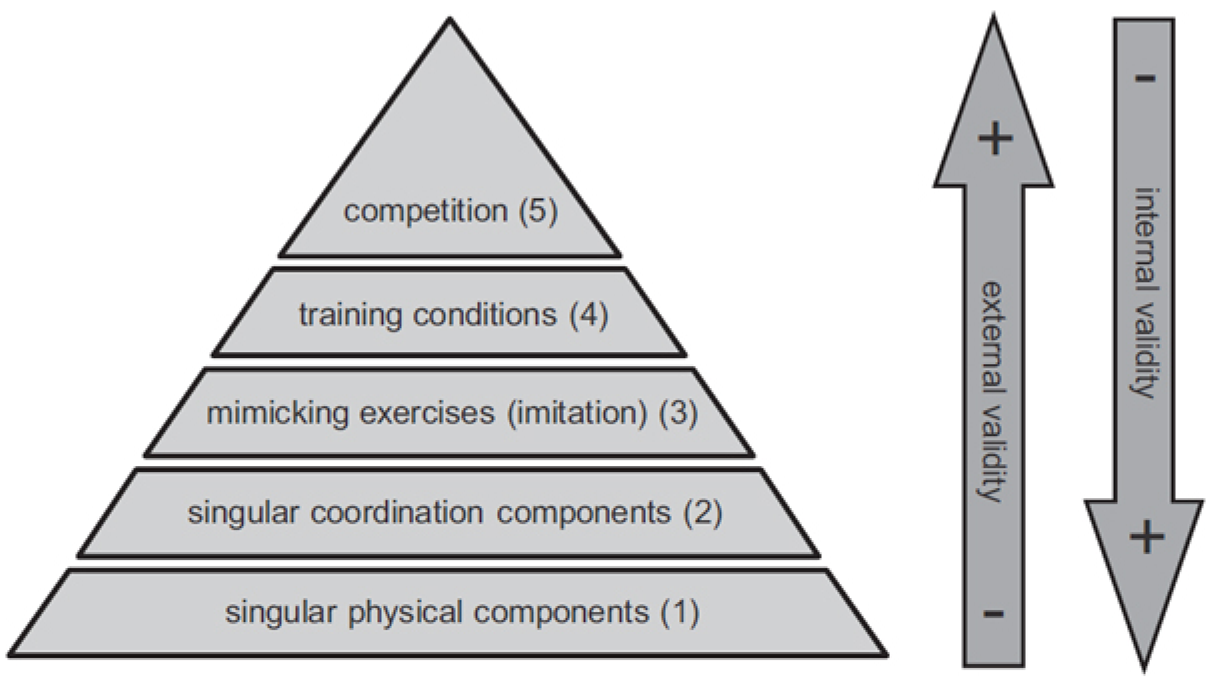

Fig. 2: Levels (1-5) of experimental biomechanical research with related external and internal validity.

Biomechanical ski jumping research is dominated by using the classical methodology kinematics, dynamics and electromyography.

Table 1 presents an overview on the usability of the methodologies with respect to the different levels of experimental biomechanical research (Fig. 2).

Within the kinematic methodology the video technique plays the major role in ski jumping research. In principle, video technique can be used in all levels of experimental research and can be applied in both ways, with fixed and with panned/tilted camera configurations (Virmavirta et al. 2005; Schwameder & Müller, 1995). Another kinematic methodology is based on initial measurement units (IMUs) consisting of a combination of gyroscopes, magnetometers and accelerometers. They have already been successfully used for measuring the orientation of body segments over the entire hill jump (Chardonnens et al., 2010). Force plates measuring ground reactions forces in three dimensions are widely used for imitated take-offs and performance diagnostics. Pressure insoles are commonly used for determining ground reaction force in both hill jumps and imitated take-offs (Virmavirta & Komi, 2001; Virmavirta et al., 2001; Schwameder, 2007). Several take-off platforms are already instrumented with force plate systems for measuring ground reaction forces perpendicular to the platform in hill jumps. Due to the high importance of aerodynamic forces in ski jumping their determination in wind tunnel experiments has a very long tradition and is still widely used for improving the flight position, but also for measuring the effect of specific equipment (suits, helmet, skis, binding) on the aerodynamics in ski jumping. Surface EMG is commonly used for investigating muscle activation and muscle coordination patterns both in hill jumps and imitated take-offs.

		level 1	level 2	level 3	level 4	level 5
Kinematics	Video, fixed cameras	+	+	+	+	+
Kinematics	Video, panned and tilted cameras	o	o	+	+	+
Kinematics	IMUs	o	+	+	+	
Dynamics	Force plates (3D)	+	+	+		
Dynamics	Pressure insoles	+	+	+	+	
Dynamics	Force plates in take-off platform				+	+
Dynamics	Aerodynamics (wind tunnel)			+		
Electromyography	Surface EMG	+	+	+	+	

Tab. 1: Biomechanical methodology used in ski jumping research on the different levels of experimental scientific work (see Fig. 2). +: possible and plausible, o: possible, but not necessary

3 Imitated take-offs

Imitated take-offs are commonly used in ski jumping conditioning and coordination training as well as in performance diagnostics. Usually they are performed as dryland exercises from static or quasi-static in-run positions with a subsequent take-off movement imitating the take-off in hill jumps (Fig. 3). In elite jumpers imitated take-offs show very high consistency in terms of reproducibility and variations (e.g. in-run position, underground, additional tasks) can be implemented and performed easily. Imitated take-offs suppose to have very high coordinative affinity to hill jumps. If one looks at the boundary conditions (aerodynamics, friction, duration) between imitated take-offs and hill jumps carefully, however, this assumption has to be challenged.

Fig. 3: Kinematic sequence of an imitated take-off

It has to be considered that the boundary conditions of hill jumps and imitated take-offs differ substantially. While the friction between the skis and the ground (snow, porcelain) are close to zero and the drag is high in hill-jumps, in imitated take-offs the situation is vice-versa: high friction between the boots and the ground and no drag (Fig. 4).