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International Ski and Snowboard Federation consensus statement on warm-up and cool-down in competitive alpine and freestyle skiers and snowboarders

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ABSTRACT

In diverse sports, warm-up (WUP) and cool-down (CD) activities are highly effective at improving performance-relevant factors and reducing the risk of injury when applied systematically; however, scientific evidence is widely lacking in snow sports. Similarly, there is a lack of international harmonisation with current best practices; this especially applies to prevention efforts targeting younger athletes. This International Ski and Snowboard Federation (FIS) consensus statement aims to develop and promote recommendations regarding physical and psychological WUP&CD in competitive alpine and freestyle skiers and snowboarders. The selected panel members represented a group of experts diverse in terms of gender, expertise/background, level of competition and skiing and snowboarding discipline. They included researchers, officials, physicians, physiotherapists, coaches or former athletes with extensive experience in the subject area. However, there was a gender imbalance in the composition of the panel (7 women and 13 men) and certain freestyle disciplines (eg, aerials and moguls) were under-represented. Most importantly, there was a strong over-representation of European members (85%) on the consensus panel. For the consensus process, the RAND-UCLA Appropriateness Method was used. The panellists were asked to rate, discuss and rerate statements derived from the literature or expert/panellist opinions. The process was based on three online consensus sessions with different preparatory and follow-up tasks and three rounds of an online survey to vote on the statements. The final version of the FIS consensus statement was developed and approved after two iterative rounds of manuscript revision by the panel members. It is intended to guide athletes, coaches, medical staff of international and national federations and other entities who can promote and support appropriate WUP&CD practices for competitive alpine and freestyle skiers and snowboarders by providing support, resources or infrastructure.

INTRODUCTION

The snow sport disciplines of competitive alpine and freestyle skiing and snowboarding are each characterised by specific features, such as physical and psychological skill requirements, equipment used, course design and competition formats. Thus, these aspects require tailored approaches for performance enhancement and injury prevention. For example, skiers and snowboarders in the alpine and freestyle disciplines must withstand enormous forces, which can reach several times their body weight and pose serious health risks while turning and/or landing jumps.[1–7] Moreover, they train and compete in the cold, often at temperatures below zero, whereas their competition clothing is, for performance reasons, thin and aerodynamically optimised, but not particularly thermoregulating. These sporting situations place unique and complex physical, psychological and contextual demands on athletes that substantially differ from those of other sports and pose significant sport-specific and setting-specific challenges for both their short-term and long-term preparation.

A key approach to address these demands in competitive alpine and freestyle skiing and snowboarding is warm-up (WUP) and cool-down (CD) activities before and after training/competition.[8 9] In various sports, such activities are effective for improving performance-relevant factors and reducing the risk of injury when applied systematically.[10–19] From the non-snow sport-specific context, it is known that WUP&CD activities

may be particularly beneficial for increasing/decreasing body temperature, stimulating/downregulating the body and mind, and, overall, preparing/adapting athletes to the demands of sports participation.[20–23]

In the context of snow sports, however, there are only a few scientific insights into the topic of WUP&CD, and the majority of them are related to downhill-oriented or jump-oriented snow sport disciplines such as competitive alpine and freestyle skiing and snowboarding.[9 24–28] In terms of content, the available literature focuses on the physiological–pathophysiological mechanisms of cold/subzero exposure, while recommendations are derived directly from these mechanisms.[24 25 29–32] A few other studies that focus on snow sports athletes in particular (1) analyse the effects of WUP&CD activities on body temperature and physiological measures[26 27 33] or (2) systematically compile knowledge about current WUP&CD practices.[9 28 34]

A recent scientific source on the latter focus is the study by Beck *et al*, who (as a preceding step of this consensus statement) examined WUP practices in high-performance snow sports to describe their importance, application and possible improvements from the perspective of athletes and staff.[9] In this study, which was conducted by a subgroup of this consensus panel, we reported that the broad implementation of basic physical and psychological WUP activities at the youth level is perceived as an important measure to increase the overall adoption of such activities as an integral part of training and competition.[9] At the elite level, however, basic WUP activities should become increasingly specific and individually adapted to the loads, environmental conditions and circumstances of day X.[9]

Apart from these few sources of snow sport-specific evidence, there is a lack of international harmonisation and consensus with recommendable evidence-based WUP&CD best practices. This particularly applies to measures aimed at youth and adolescent competitive alpine and freestyle skiers and snowboarders. Accordingly, we aimed to develop consensus-based recommendations for physical and psychological WUP&CD before and after on-snow training or competitions, with a particular focus on youth and adolescent athletes.

METHODS

Panel selection

The first author (JSp) was commissioned by the International Ski and Snowboard Federation (FIS) Athlete Health Unit to work with an international group of experts to develop evidence-informed best practice recommendations regarding reasonable WUP&CD activities in the context of competitive snow sports. In a discussion with EV, JSp identified and invited 20 members for a consensus panel. The panel members were researchers, former athletes or team staff of the National Ski and Snowboard Associations (NSSAs), that is, officials, physicians, physiotherapists and coaches, with extensive experience in the subject area. They served as the authors of this consensus statement. Their names, institutions and geographical locations can be found in the author information.

Equity, diversity, and inclusion statement

The selected panel members represent a group of experts, diverse in terms of gender, expertise/background, level of competition and ski and snowboard subdisciplines. However, despite our best intentions and efforts to achieve a balanced consensus panel, there are limitations regarding the diversity of the consensus panel that must be noted. There was a gender imbalance in the composition of the panel (7 women and 13 men). The various professional skills/backgrounds and levels of competition relevant to competitive alpine and freestyle skiing and snowboarding can be considered well represented; however, the perspectives of certain freestyle disciplines (eg, aerials and moguls) were underrepresented, as were the Nordic disciplines of cross-country skiing, ski jumping, Nordic combined and biathlon. Most importantly, there was a strong over-representation of members from Europe on the consensus panel, with only one member representing North American, South American and African perspectives and no experts from Asia, Australia or New Zealand. These limitations may have influenced the results of the current consensus process and may have given the recommendations a European and alpine skiing biased lens.

As a concrete countermeasure to these limitations in terms of the diversity of the consensus panel, the statements to be voted on were not only proposed by the consensus panel members but were also derived from the literature[8] and a preceding qualitative interview study investigating the perspectives of athletes and team staff on WUP practices in high-performance snow sports.[9] For more detailed information on the consensus process methodology, we refer to online supplemental material-file A. In this preceding qualitative interview study with 13 international elite athletes, on-snow coaches, strength and conditioning coaches, sports physiotherapists and sports psychologists from different snow sports and subdisciplines, gender, expertise/background, level of competition, representation of ski and snowboard subdisciplines and geographical origin were more equally distributed than in the consensus panel. In particular, the non-European perspectives from North America, Asia and Australia/New Zealand as relevant continents for international competitive snow sports, which are underrepresented/lacking in the present consensus panel, were adequately included in this base study. This is likely to increase the diversity of perspectives underlying our final consensus statement recommendations.

Patient and public involvement

A former world-class athlete in alpine skiing (TW) was included in the consensus panel to foster active patient and public involvement. Her role was to give the athletes' viewpoints a voice and, at the same time, ensure the practicability of any recommendations discussed. In addition,

one of the panel members (LB) provided insights into freestyle disciplines, particularly from the perspective of a former world-class freestyle snowboarder and a current team physiotherapist and researcher in freestyle skiing and snowboarding.

Evidence review

The current consensus statement was developed following available topic-relevant literature identified via a PubMed search by the panel chair dated 18 August 2022 (and updated 26 June 2024). For this purpose, the following key term searches were performed: alpine ski*; cross-country ski*; ski jump*; freestyle ski*; freeski*; snowboard*; warm-up AND athlete; cool-down AND athlete; and 'post-exercise recovery' AND athlete. Eligible studies originated from the competitive sports context and were published in 2017 or later. The articles identified in this way were made available to the panel members at the beginning of the consensus process and (in an updated version) at the beginning of the paper-writing process as a digital data repository.

Overall, the topic-specific and snow sport-specific studies identified were sparse, and only six studies dealt directly with the topic of WUP&CD in snow sports athletes (four studies since 2017[9 27 33 34]; six studies in the last 25 years[9 26–28 33 34]), which highlights the lack of scientific evidence to date. Owing to the few relevant articles, we decided not to systematically summarise the available research, as it was relatively easy for the panel members to gain an overview of the current state of knowledge as a basis for their discussions.

Consensus process

For the consensus process, the RAND-UCLA Appropriateness Method[35] was used, which systematically and quantitatively combines expert opinions and evidence by asking panellists to rate, discuss and rerate statements derived from the literature or expert/panellist opinions. The detailed consensus process is outlined in the online supplemental material-file A.

Our initial best intention was to address the lack of international harmonisation and consensus on current evidence-based best practices regarding WUP&CD in all snow sport disciplines. However, based on the fact that (1) significant topic-relevant differences between downhill and endurance-oriented snow sport disciplines, (2) the fact that most topic-relevant studies thus far have focused on the discipline of alpine skiing and (3) the fact that most of the WUP&CD experts identified for panel selection had professional backgrounds in alpine and freestyle skiing and/or snowboarding, we finally defined the scope of this consensus statement to be restricted to competitive alpine and freestyle skiers and snowboarders. Nevertheless, at least some of the more general recommendations may also be transferable to other snow sport disciplines with similar organisational settings, such as cross-country skiing, ski jumping, Nordic combined, biathlon or ski mountaineering, whereas further initiatives are needed to fully address WUP&CD in these sports.

CONSENSUS RESULTS

The primary outcome of the consensus process described above was a list of 160 statements derived from the literature and expert/panellist perspectives, on which the consensus panel discussed and voted during three consensus meetings and as part of three rounds of surveys. The full statement list with the detailed voting results and action choices can be found in online supplemental material-file B. In the following, direct reference to individual statements is made by indicating their numbers according to this list. A summary of the voting results and action choices as part of the three voting rounds is presented in online supplemental material-file C.

CONSENSUS DEFINITIONS

Key terms

For a common language in relation to WUP&CD in the competitive alpine and freestyle skiing and snowboarding context, table 1 provides the consensus-based definitions and clarifications of key terms. Despite the clear distinction between these key terms, the panellists agreed that their relationship is interactive (**#13**).

Key concepts

When planning and implementing WUP&CD activities in competitive alpine and freestyle skiers and snowboarders, our consensus panel recommends that end users be guided by the key concepts described below.

Readiness versus preparedness

An important purpose of WUP&CD activities is to increase athletes' immediate readiness. Readiness refers to physiological and psychological processes such as corticospinal excitability, motor unit activation and the ability to focus on functioning at the maximum level (**#21**). In such a way, movement efficiency, awareness, responsiveness and performance motivation can be maximised (**#21**). Moreover, readiness may (also) be understood as a subjective feeling that includes physical and psychological aspects (**#22**). One example to illustrate this is the individual routines that athletes go through immediately before a competition to be as mentally focused and physically engaged as possible for the subsequent competition.

However, another important purpose of WUP&CD activities in terms of cumulative beneficial adaptations is to increase athletes' preparedness. Preparedness refers to athletes' short-term, mid-term and long-term development to meet their physical and psychological sports demands (**#23**). This can be considered an effect of the aggregation of WUP&CD effects over time. Accordingly, WUP&CD should include activities with an immediate effect and more long-term performance-related or health-related components, such as physical/psychological conditioning or skills training. Two examples for this purpose are the off-snow and on-snow training

Table 1 Consensus-based definitions and clarifications of key terms

Term	Definition and clarification
Preparation	*Preparation includes all physical and mental preparatory activities that typically occur >20 min before a training session or competition and aims at maximising performance or protecting the health of athletes (**#1**).*
Warm-up (WUP)	*Warm-up includes all physical and mental preparatory activities that typically occur <20 min before a training session or competition and aims at increasing the heart rate, blood flow and body temperature as well as mobility, proprioception, stability and muscle activation levels (**#6**).*
Activation	*Activation includes increasing the mind-muscle connection by upregulating corticospinal excitability and motor unit conduction velocity and lowering activation thresholds of muscle fibres and aims to achieve the individual optimal balance of physical, mental and emotional stimuli* (**#12**).
Stretching	*Stretching aims at the elongation of muscle-tendon units and on improved flexibility* (**#14**).
Mobilisation	*Mobilisation means increasing or maintaining the ability to move a joint either actively or passively through an available range of motion in order to be able to achieve all needed positions during the sporting activity* (**#15**).
Cool-down (CD)	*Cool-down aims on the downregulation of the sympathetic system and the upregulation of the parasympathetic system following a training session or competition* (**#17**).
Recovery	*Recovery means returning to a situation in which athletes can perform again and should consider a physical and mental dimension* (**#20**).

The indicated statement numbers relate to those of the full statement list in the online supplemental material-file A.

programmes presented by Westin *et al* and Schoeb *et al*,[36 37] whose effectiveness in preventing injuries in youth competitive alpine skiing has been demonstrated and which could also be performed as part of a competitive alpine and freestyle skiers and snowboarders-specific WUP.

Raise, Activate, Mobilise, Potentiate

The RAMP (Raise, Activate, Mobilise, Potentiate) protocol is a clear, sport-independent structure and content guideline for WUP that may also be applicable in snow sports and in competitive alpine and freestyle skiers and snowboarders in particular (**#24**). As originally introduced and promoted by Jeffreys,[38] RAMP may serve as a structured approach that classifies the WUP phases and allocates relevant content to them. Indeed, snow sports athletes and staff reported using/promoting WUP activities on the basis of or resembling the RAMP protocol in their daily practice.[9]

The Raise phase aims to increase body temperature, heart rate, respiration rate, blood flow and joint fluid viscosity via low-intensity activities.[38] This first phase should be used to increase short-term readiness and improve long-term preparedness; as such, it should be dedicated to movement skills or strength and conditioning drills relevant to the sport.[38] In the subsequent Activate and Mobilise phases, key muscle groups relevant to a particular sport should be activated, and the key joints required for this sport should be mobilised.[38] These two phases should also address the individual needs of athletes.[38] In the concluding Potentiate phase, the aim is to improve the effectiveness of subsequent performance through sport-specific activities with increasing intensity up to the super-maximal load and by utilising the postactivation potentiation (PAP) effect.[38]

CONSENSUS RECOMMENDATIONS

Table 2 summarises the most important content and recommendations of the current FIS consensus statement on WUP&CD before or after on-snow training and competition in relation to competitive alpine and freestyle skiers and snowboarders.

WUP&CD: WHY?

Despite the current controversy in the literature about the acute and long-term effectiveness of WUP&CD for acute and long-term performance enhancement and injury prevention in various sports settings and the limited number of scientific studies in this regard,[10 14 15 17 20 23 39–46] our consensus panel considers these purposes relevant and plausible rationales for conducting WUP&CD activities in competitive alpine and freestyle skiing and snowboarding. This is also in line with the perspectives of athletes and staff from the snow sports community, who described being ready as a key factor for performance and injury prevention.[9]

Performance enhancement

According to our consensus discussions, plausible arguments for WHY performing WUP&CD in the competitive alpine and freestyle skiing and snowboarding context are as follows: physiological AND psychological activation may enable the body to perform at its best (**#28**). In this context, WUP may increase athletes' long-term preparedness and short-term readiness (**#37**) and, thus, performance (**#38**). In the short term, WUP is expected to improve muscle function (reaction, neuromuscular function, mobility, proprioception and cognitive function) in the ranges required for the sport, thus enhancing performance (**#26**). As such, it may help athletes exploit their potential to 100% but not to generate additional performance potential (**#27**). In the long term, especially

Table 2 Overview of the main contents and recommendations of this consensus statement

Topic	Contents/recommendations
WUP&CD: WHY?	WUP&CD activities are considered beneficial to increase body temperature, stimulate the neuromuscular system and, overall, physically and psychologically prepare competitive alpine and freestyle skiers and snowboarders for the demands that come along with the participation in their sports. In particular, WUP&CD activities may generally serve two purposes: (1) performance enhancement and/or (2) injury prevention; end-users should be made aware of the potential benefits for both purposes.
WUP&CD: WHAT?	WUP: Sports readiness may be achieved by reaching readiness in its physical and mental subdimensions. Measures for increasing physical readiness should address the cardiovascular system (sustained or interval mid-intensity movement), the musculoskeletal system (increasing muscle temperature, sport-specific exercises with isometric or eccentric contraction modes), the metabolic system (intensive WUP exercises close to the competition load, and sufficient fuel and hydration) and the motor system (neuromuscular, neurocognitive and proprioceptive exercises, as well as on-snow WUP runs). Measures increasing the mental readiness should target psychological mechanisms related to managing attention, focus, mindfulness, levels of arousal, executive function, self-confidence, motivation, distress, anxiety and mental fatigue. CD: Cool-down should include activities related to physical, mental and emotional regeneration and can be either active (low-intensity to moderate-intensity cardiovascular and/or resistance exercises, and psychological recovery strategies such as imagery or relaxation) or passive (stretching, water immersions, compression garments, massage, vibration, nutritional strategies and sleep).
WUP&CD: HOW AND WHEN?	WUP&CD may include a variety of activities during the same day (preparation, immediate WUP, immediate CD and recovery). When continuously and systematically applied they may also be used for increasing athletes' long-term preparedness and counteracting their deficits.
WUP&CD: WHERE?	WUP&CD activities can be performed off-snow (eg, at the hotel/sports hall/lift station/team hospitality), where they can be carried out with training shoes, and on-snow (at the run-in hill/slope/start area), where activities with ski/board boots and WUP runs on the hill can be performed.
WUP&CD: WHO?	Routines are key to compliance and consistency of WUP&CD efforts. At youth levels, coaches (and if available, physiotherapists) are mainly responsible for developing and implementing WUP&CD routines. At elite levels, physical therapists and conditioning coaches should assist in individualising and ensuring compliance with WUP&CD routines.
Contextual adaptations	To guarantee the feasibility, effectiveness and acceptance of WUP&CD activities, contextual aspects to be considered include individuality, level, sex/gender, sociocultural factors, setting and the targeted snow sports discipline. Competitive alpine and freestyle skiing and snowboarding-specific recommendations in this regard are provided, and potential facilitators and barriers of WUP&CD are discussed.

in younger athletes, WUP&CD can also help set appropriate training stimuli and work on weaknesses (**#27a**), thus increasing their preparedness and potential to perform. Whether CD can increase long-term preparedness has been acknowledged as a matter of debate (**#37a**); however, WUP&CD can plausibly improve training quality and thus (at least) enhance performance in the long term (**#39**).

Injury prevention

According to our panel discussions, in addition to enhancing performance, physiological and psychological activation may (also) enable the athlete to perform as safely as possible (**#34**), and WUP&CD has the potential to decrease the risk of (re)injury (**#40; #41**). In the short term, WUP&CD is, again, expected to improve muscle function in the ranges required for the sport, thus preventing injuries (**#30**). Moreover, WUP can improve mobility and better prepare the body for strains during falls (**#31**) and may improve the ability to absorb and react to the external forces that act on the body (**#32**). In addition, WUP&CD can help athletes perform at (but not above) their limit without getting injured because all physical and psychological body systems are ready to operate (**#33**). Finally, WUP is expected to improve cognitive function and thus decrease the occurrence of high-risk situations such as falls or inappropriate landings (**#35**). Panel members also agreed that by putting the content of WUP&CD activities at the service of the athlete's long-term development (MACRO lens), athletes could further benefit from health protection effects through improvements in several injury-relevant factors (**#36**). For example, WUP&CD may optimise body perception and awareness (**#42),** and CD is expected to improve and accelerate recovery (**#43**).

WUP: WHAT?

Measures for increasing physical readiness

Several subsystems should be addressed through appropriate WUP activities to achieve physical readiness. Studies on the current practice of WUP activities have shown that the focus in most snow sports disciplines is

on the cardiovascular system, the musculoskeletal system, the metabolic system and the motor system.[9 28 34] In addition, across various sports, current evidence indicates that increasing body temperature, cardiovascular readiness, musculoskeletal readiness, metabolic readiness and motor readiness is possible[21 22 26 27 33] and that WUP may be an efficient strategy to prevent diurnal variation in short-term maximal performance.[47] Finally, sports-independent evidence shows that to increase athletes' physical readiness, passive WUP (with heat garments),[21 22 48 49] active WUP (with exercises),[20–22] and, in particular, a combination of both is effective[27] and that shorter and more specific WUP programmes can be just as effective as long traditional WUP programmes.[33] On the basis of this background, we recommend that WUP should address all of the aforementioned subsystems of physical readiness.

Cardiovascular readiness

Cardiovascular readiness may be achieved by sustaining or interval mid-intensity movement (**#47**). However, altitude, temperature and transition times must be considered, as they influence cardiovascular readiness (**#48**).

Musculoskeletal readiness

Musculoskeletal readiness may be achieved by movement at large ranges of motion (ROMs), potentially emphasising competitive alpine and freestyle skiing and snowboarding-specific isometric or eccentric contraction modes (**#50**). In this context, muscular WUP should be as sport-specific as possible (**#51**). WUP activities that address the leg, trunk or upper body in isolation and complex forms of exercise that address all areas are recommended (**#51a**). Moreover, muscle temperature and, thus, ambient body temperature should be considered for achieving musculoskeletal readiness, as increased muscle temperature is needed for power production (**#52**) and additional passive WUP activities may be considered to keep key muscles warm (**#53**).

Metabolic readiness

Metabolic readiness can be achieved by conducting cardiovascular and musculoskeletal warming-up (**#54**). Moreover, it may also be achieved through intensive WUP exercises performed approximately 15 min before the start, with lactate values close to the competition load. Thus, all metabolic systems are switched on, and the oxygen uptake kinetics are optimised. In addition, the use of lactate as a signalling molecule positively affects mental readiness (**#55**). Metabolic readiness may be supported by sufficient fuel and hydration intake (eg, gels, drink) (**#56**).

Motor readiness

Motor readiness may be achieved by neuromuscular activation, coordination exercises and some key proprioceptive exercises (eg, a single leg landing with perturbation, eventually closed eyes to prepare for harsh weather conditions), and sport-specific movements with progressively increasing intensity (**#57**). It may also be achieved by preparing as specifically as possible for the actual movement task (eg, on-snow running-in; optimally with gates, jumps or park elements or runs on the slope) (**#58**). Accordingly, 2–3 runs on slopes and mental exercises (eg, breathing, visualisation, mindfulness exercises, self-talk) can help activate sport-specific skills and cognitive functions and prepare mentally (**#45**).

Measures for increasing mental readiness

It is known from diverse sports settings that to reach mental readiness, psychological mechanisms related to managing attention, focus, mindfulness, arousal levels, executive function, self-confidence, motivation, distress, anxiety and mental fatigue play important roles.[9 22 50–53] Accordingly, mental readiness can be considered to have cognitive and emotional dimensions.

Cognitive readiness

Cognitive readiness may be achieved by visualising the motion/run. Optimally, the visualised time is close to the actual running time (**#59**). Moreover, it may be supported by neurophysiological activation via sensorimotor exercises (**#61**). In addition, on-slope WUP and activation (eg, running-in descents/runs) may increase cognitive readiness, as they help to connect the body, the mind, the material and the environment (snow, vision, wind). Athletes must feel the environment to adapt their skiing/riding appropriately (**#62**). Finally, previous research on volleyball players has shown that WUP plays an important role in shortening the time of visual-motor reactions to a light stimulus[54]; accordingly, WUP exercises with the particular aim of attention control may also be recommended for skiers and snowboarders.

Emotional readiness

Approaches for achieving emotional readiness include music, visualisation, self-talk, self-regulation or correct address by the coach/supervisor at the start (**#63**).

Measures for increasing sports readiness

Sports readiness may be achieved by reaching readiness in its physical and mental subdimensions (**#65**). Therefore, physical and mental readiness must be considered an integrated whole for achieving sports readiness (**#64**). To increase the readiness specifically required in competitive alpine and freestyle skiing and snowboarding, the following WUP&CD activities may be considered before and after training/competition. The WUP&CD should comprise more than just stretching exercises (**#14a**). WUP activities impact a wide variety of interacting factors, such as those related to the cardiovascular system, the musculoskeletal system, the endocrine system, the nervous system, the visual system, the vestibular system and metabolism (**#44**). The intensities of different WUP activities are exercise specific; however, in many cases, body weight might be sufficient for unilateral leg work, bilateral arm work and core work (**#50b**). In competitive

alpine and freestyle skiing and snowboarding, the activation of the muscles around the core, hip and knee and the activation and potentiation of jump landings, single-leg stability and WUP runs are key (**#25**). Moreover, physical and mental readiness in competitive alpine and freestyle skiing and snowboarding should focus on jump landing tasks, hamstring muscles, core muscles, dynamic postural control, proprioception and adaptation to the day's conditions (eg, current snow conditions or competition format) (**#66**). Activating the neck muscles can support head stabilisation during sport-specific motion tasks (**#67**). If an unclear image of the surroundings is perceived during competitive alpine and freestyle skiing and snowboarding, this, in turn, impacts the athlete's motor stability. In this context, targeted eye or gaze training can help (**#68**). WUP runs in sport-specific on-snow training/competition environments (eg, gates, jumps or park elements) are an efficient way to prepare for a performance at the athlete's limit (**#69**). In addition, to get mentally ready, snow sports athletes and staff reported systematically using breathing, visualisation, self-talk, posture, listening to music and mindfulness exercises during their physical WUP routines or immediately after.[9] Moreover, as a competitive alpine and freestyle skiing and snowboarding-typical coping strategy for dealing with anxiety and distracting thoughts, talking to staff members or other athletes at the starting area was reported.[9] Overall, these recommendations align with the current WUP practices reported by snow sports athletes and staff.[9]

CD: WHAT?

Regarding the content of an appropriate CD, our consensus panel considers that the recovery strategies described below, widely discussed in the literature and applied in various other sports, may also be beneficial in competitive alpine and freestyle skiing and snowboarding. As such, recommended CD activities impact a wide variety of interacting factors related to physical, psychological and emotional regeneration (**#46**).

Active recovery

The active recovery strategies proposed in the general literature are low-intensity to moderate-intensity cardiovascular and/or resistance exercises that are conducted within approximately 1 hour after major training/competition loading and aim to lower athletes' physical and psychological activity levels and initiate effective recovery.[23 45] In the context of competitive alpine and freestyle skiing and snowboarding, this may include activities directly on snow but also off snow, such as jogging or stationary cycling. Additional individualised active psychological recovery strategies may include techniques such as goal setting, imagery, relaxation, motivation and self-talk, as has been proposed in rugby.[45]

Passive recovery

Recommended passive recovery strategies are, despite some controversy regarding their effectiveness in the general current literature, stretching, cold water immersion, compression garments, massage, vibration, nutritional strategies, napping and sleep.[13 19 23 39 45 55–61]

WUP&CD: HOW and WHEN?

Owing to the nature of competitive alpine and freestyle skiing and snowboarding, that is, performing outdoors and with very specific sports participation characteristics, including stopping (eg, lift rides) and going (eg, descents), the questions of HOW and WHEN WUP&CD are quite challenging and largely depend on the situation and context.

Overall framework

Figure 1 provides a schematic temporal framework drawing, including key considerations for implementing WUP&CD activities for competitive alpine and freestyle skiers and snowboarders in the corresponding phases.

Immediate WUP

A structured WUP immediately before training and competition, as well as two to three on-snow WUP runs across variable terrain, is considered the most important measures for achieving an appropriate level of readiness.[9 34] An immediate WUP occurs at the top of the course on snow before skiing/riding the course for training/racing and may also include few runs on the course/track (**#70**). The WUP practices currently being performed by competitive alpine and freestyle skiers and snowboarders include raising the heart rate and body temperature, mobilising the joints, activating the muscles and potentiating sport-specific activities.[9] WUP shall encompass perfusion, sport-specific mobility, neuromuscular activation and PAP (**#73**). During the immediate WUP (<20 min), choosing an intensity high enough to positively affect the opening of capillaries in the working muscles is important. At the same time, however, care must be taken to ensure that the athletes are recovered at the start time and do not feel prefatigued (**#49**). Additionally, being appropriately focused and emotionally ready has been described as key to reaching the required level of readiness for snow sports.[9] For some athletes, the aim is downregulation, depending on the optimal intensity state and individual intensity levels (**#74**).

Training/competition

At the beginning of training sessions or before competitions, athletes should be ready to perform as safely as possible (**#75**). Long transition times should be avoided after WUP (**#71**). Moreover, exposure to cold temperatures should be limited at extremely cold temperatures after WUP (**#72**), and additional passive WUP activities may be considered (**#53; #93; #121; 123; #124**).

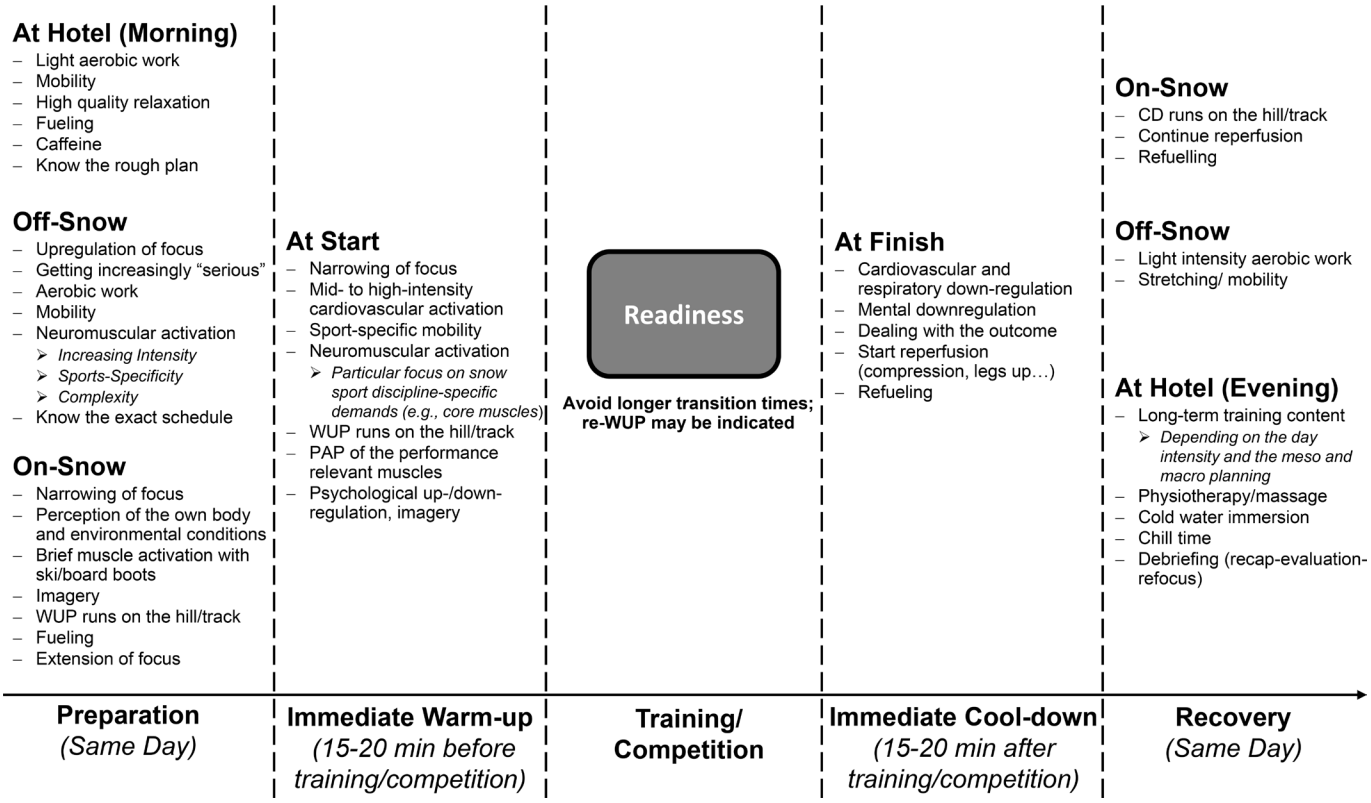

Figure 1 Temporal framework including some key considerations for the implementation of warm-up (WUP) and cool-down (CD) activities. PAP, postactivation potentiation.

Immediate CD

The immediate CD should encompass, whenever possible, passive or active reperfusion, lowering respiration, restoring energy and mental downregulation (**#76**). In competitive alpine and freestyle skiing and snowboarding, however, immediate CD can be difficult to achieve, especially in races, as athletes may not have access to equipment or facilities before they return to their accommodations (**#77**).

Placement in the bigger picture

WUP&CD in competitive alpine and freestyle skiing and snowboarding should not only be limited to the immediate time before, during and after training and/or competition but should also consider a much wider context.

Broader activities during the day

Broader preparation activities during the same day should include general mobility, general neuromuscular activation, fuelling and anticipation of the general daily conditions (weather, snow, etc) (**#78**). Regarding mental preparation, psychological strategies such as focus, emotion regulation and imagery are perceived to play a key role.[9]

Broader recovery activities during the same day may include passive or active reperfusion, mobility, refuelling, massage, physiotherapy and cold-water immersion (**#79**). In addition, despite a lack of evidence for its effectiveness in enhancing recovery in various sports,[55] stretching sessions after exercise are recommended as part of general activities during the day, although more for long-term maintenance of mobility. With respect to mental recovery, debriefing, including a recapitulation and evaluation of the day aiming to plan and refocus on the next day, may play an important role in the recovery routines of competitive alpine and freestyle skiers and snowboarders.

Long-term development

With respect to the long-term development of WUP&CD, simple sport-specific basic exercises should be performed at the youth level to facilitate athlete compliance. More individualised exercises should be performed later in the career once WUP&CD has become a clear and essential routine (**#80**). WUP should be seen as a mini training session, an extension of training and practice, which can develop strength, agility and mobility and enhance neuromotor control (squat and single-leg squat patterns), balance and coordination. Corrective and prevention exercises can be included to work on movement inefficiencies and to practise good motor patterns (**#81**). In addition to general long-term athlete development, WUP could include athlete-specific exercises to improve neuromuscular skills (**#82**). Athletes need to learn to reach mental readiness as part of their long-term development (**#83**). WUP&CD activities should be reflected

continuously and refined over time to optimise their effectiveness (**#86**). Accordingly, macrolevel programming of WUP&CD should aim to develop individualised WUP routines and general preventive strategies (**#87**).

WUP&CD: WHERE?

Like the HOW and WHEN questions of WUP&CD, the WHERE question also poses sport-specific challenges and largely depends on the situation and context. Expert stakeholders from the snow sports context clearly and timely distinguish between off-snow activities (somewhere inside, where it can be done in training shoes, as ski boots may hinder efficient WUP activities) and on-snow WUP activities (activities with ski/board boots and WUP runs on the hill).[9]

Off snow

WUP&CD activities performed off snow (at the hotel/sports hall/lift station/team hospitality) should have their place/rank in the training routine. They may be supported by additional available equipment (**#88**).

On snow

Active WUP&CD activities conducted on snow (at the run-in hill/slope/start area) should be simple and doable with minimal additional equipment (**#89**).

WUP&CD: WHO?

The WHO question is very relevant for implementing WUP&CD, as it is generally well known that ownership plays a major role in motivation[62] and, therefore, compliance with recommended exercise activities[63] such as WUP&CD.

Responsibilities

At the youth level, coaches (and, if available, physical therapists) are mainly responsible for developing and implementing the routine of warming up and cooling down (**#90**). At elite levels, physical therapists and conditioning coaches should assist in individualising and ensuring compliance with WUP&CD routines (**#91**). In addition, the team staff may support the athlete by checking the timing during competitions to ensure enough time for re-WUP (**#92**), as well as by lapping with the athlete in very cold conditions and carrying a coat or blanket for passive WUP right after the run (**#93**). Finally, staff must support athletes if they have difficulty reaching readiness on a specific day (**#106**).

The role of routines

Routines are key to compliance with and consistency of WUP&CD efforts (**#95**), and routines can help to practise achieving readiness (**#96**). Once a routine for WUP&CD is established, it becomes part of the process and decreases the mental energy required to perform it, even creating space to prepare mentally (**# 94**). In developing individual WUP&CD routines in the direction of top athletes, the individual needs of the athletes should be increasingly considered. At the youth level, however, athletes should learn what they need (**#97**).

Contextual adaptations

Different contextual aspects must be considered to ensure the practicability, effectiveness and uptake of WUP&CD activities.[9] Snow sports athletes and staff particularly mentioned the need for adaptation to different athlete-specific, environment-specific and task-specific factors to reach readiness.[9] Thus, contextual adaptations are key once basic WUP&CD routines have been established. At this point, we would like to note the very limited number of studies dealing with the implementation of snow sport-specific interventions, particularly WUP&CD activities. Like in other sports,[46 64] also in competitive alpine and freestyle skiers and snowboarders (and other snow sport disciplines), more data are needed on end-user perceptions and behaviour regarding WUP&CD and their impact on performance and injury.

Individuality

According to stakeholders, individualising WUP&CD activities is highly important in snow sports, as the way to achieve readiness may vary from athlete to athlete.[9] In this context, the individualisation of WUP is described as a process in which athletes learn what is best for them through trial and error.[9] Accordingly, for individualisation, a physiotherapist or strength and conditioning coach should identify individual physical areas requiring attention (weakness, laxity, hypomobility, etc) beforehand and address them in WUP if relevant to the sport (**#98**). Then, physiotherapists, strength and conditioning coaches, sports psychologists and on-snow coaches should provide inputs to compose individualised WUP&CD routines during the preparatory season and adapt them if needed (**#99**). Finally, the WUP&CD routine should be implemented with an educational mindset from coaches to transfer knowledge to younger athletes, providing them with a basis for developing independence (**#100**).

Level

At the youth level, athletes should be guided to perform a general WUP&CD to develop a routine for movement literacy, competency and training (**#126**). The fact that staff resources are often limited at the youth level must be considered when planning and implementing WUP&CD activities for youth athletes.[9] Group-based and basic WUP&CD programmes may facilitate coachability (**#127**).[9] Moreover, at the youth level, WUP&CD should be adapted to level-specific needs (**#129**) and should be gender-equitable (**#130**). Later, as athletes progress to elite levels, WUP&CD routines should gradually become more individualised to address specific issues (**#128**).

Sex/gender

In the context of WUP&CD, there is a need to increase awareness of sex/gender norms, assumptions and taken-for-granted practices that may have become institutionalised in the sports environment (gender biases,

attitudes, values, norms, practices, policies, language, framing, underpinning assumptions and research) (**#137**). Overall, gendered environments, accessibility and sociostructural factors (ie, norms, practices and relations regarding implementation) are necessary to develop and individualise WUP&CD routines (**#101**).

Sociocultural

Concerning WUP&CD, there may be sociocultural differences in accessibility, cost (financial and time), beliefs, values, norms and attitudes that need to be considered (**#138**). Different snow sport disciplines may have different performance cultures (creative/stylistic vs preset/timed); these differences should be addressed through a specific WUP&CD (**#139**). In this context, a study in competitive alpine skiing has already demonstrated that nationality and sociocultural factors influence athlete development and sports outcomes in general.[65]

Setting

Adaptation to weather and outside temperature

Weather is a potential barrier that snow sports athletes have to cope with.[9] In snow sports, WUP and activation may help adapt to different environmental factors (eg, view, snowfall, temperature, snow conditions and wind) (**#136**). Preparation for different WUP scenarios should occur in advance (**#114**). Changing weather conditions and breaks in the course should be communicated to the athletes immediately, allowing them to adjust their WUP activities accordingly (**#105**). Aspects of body temperature (eg, low peripheral body temperatures) are critical situational challenges that may require situational adjustments of WUP&CD routines (**#111**). For example, a reduced capacity of the neuromuscular system in the cold can be a contributing factor to a greater risk of anterior cruciate ligament (ACL) injury after prolonged exposure to cold.[24] Preparation for cold days must be planned (clothing, heat garments, beverages, shelter) (**#117**). Warm clothing/over clothing is key to maintaining proper body temperature before a training session or competition begins (**#110**), as wearing warm, highly functional, wind-resistant and water-resistant clothing effectively adapts to harsh weather or cold conditions (**#108**). Staff may help athletes with passive WUP activities (eg, bringing the coat down so the athlete can wear it on the lift) (**#124**). After WUP, care must be taken to keep the muscles warm, depending on the outside temperature and possibilities at the start (**#109**). In this context, the local proximity to mountain lodges is considered a major challenge in training and competition in snow sports.[9] Competition organisers should (wherever possible) provide shelter from the elements in an area close to the start, and teams should each have at least a long coat to be used for the next athlete should there be a start-stop (**#141**). A shelter from the wind is the easiest, most cost-effective method (**#142**). A heated tent or special WUP facilities at the start will help athletes prepare better (**#143**).

Adaptation to locations, available infrastructures and given schedules

The place where the WUP&CD phases are carried out should be adapted to the respective conditions (**#102**). Accessibility to dedicated WUP&CD areas (eg, familiarisation tracks or retreats with limited public access) is crucial for athlete preparation and recovery (**#115**). Event organisers should provide a location for athletes with sufficient space to go through their WUP routines (including WUP runs) (**#116**). Moreover, they should consider the proximity of the WUP location to the training/competition venue and provide WUP equipment (eg, stationary bikes with enough space) (**#113**). In particular, well-prepared WUP courses are crucial for athletes' preparation, and their provision should be taken seriously (**#104**). In addition, a lack of time can be a potential barrier. Accordingly, WUP (baseline, passive, re-WUP) should always be included as an inherent part of the training and competition in planning (**#112**). In this context, factors such as bib number, race breaks and starting time must be considered when planning and structuring the WUP before a competition (**#103**).

Training/competition holds and rewarming up

Snow sports athletes and staff consider repeating their WUP or parts of it (hereinafter called re-WUP) after waiting, especially during competitions in disciplines that include more than one run.[9] Depending on the length of hold, an option and time for re-WUP should be offered to the athletes at the start gate (**#120**). In this context, the results of a recent snow sport independent study by Yamashita *et al* suggested that high-intensity, short-duration re-WUP may be a useful strategy for improving subsequent performance in cold environments.[32] Re-WUP is recommended after any transition time to ensure readiness during a run, and passive WUP activities may be considered during waiting times (**#121**). Particularly, after training or competition interruptions of more than 15 min, another WUP may be indicated (**#122**). Long lift rides also indicate passive WUP activities and a re-WUP (**#123**).The layering and use of heating devices during holds (heated socks and gloves, heated vests, heat packs for hands, etc) should be promoted (**#118**). Staff should especially help young athletes with the timing of the re-WUP (**#125**) and educate them about how to address short-term changes such as interruptions in the course (**#107**). Moreover, adequate time must be allowed in training or competition schedules for WUP&CD (**#144**). Competition interruptions should allow for the appropriate time for preparation, which may vary depending on environmental and competition considerations (**#146**). Dedicated time should always be set aside in the day plans to allow for (re)warming up and properly preparing to train/race (**#148**).

Snow sport disciplines

Our consensus panel has the opinion that, despite representing different sports frameworks, the

purposes and general content dimensions of WUP & CD can be considered universal across competitive alpine and freestyle skiing and snowboarding subdisciplines. This is further supported by a preceding qualitative interview study among various competitive sports, which also did not find relevant differences regarding immediate WUP practices across different competitive alpine and freestyle skiing and snowboarding subdisciplines.[9] This may be owing to the fact that these subdisciplines all involve similar physical loading patterns of the lower extremities and the trunk (eg, high forces and low-frequency vibrations, eccentric muscle loading and unphysiological joint and trunk positions)[1–6 66–76] for which athletes must be effectively prepared,[36 37 65 77 78] and physiological challenges to the cardiopulmonary system when exercising in subzero conditions[79 80] for which athletes should be made ready.[33] Accordingly, for competitive alpine and freestyle skiers and snowboarders of all subdisciplines WUP routines should address maximal concentric and eccentric muscle activation patterns in all planes of movement in sport-specific demand (**#131**). Moreover, neuromuscular activation of proper jump landing biomechanics and single-leg stability (**#132**), neuromuscular activation of the core, hip and knee (**#133**), the combined frontal bending, lateral bending and axial rotation of the spine under load (**#134**) and psychological activation of cognitive and emotional functions as part of mental readiness (**#135**) should be emphasised. Finally, the cardiopulmonary system should adapt to cold environments for enabling the body to perform best. However, there is currently little scientific evidence on how this can be generally best achieved, and further research on this subject matter is needed.[80]

Facilitators and barriers to WUP&CD

Beliefs, values, norms and existing attitudes influence behaviours towards WUP&CD activities (**#151**). A recent systematic review by Lutz *et al* identified comprehensive workshops and the accessibility of resources as the main facilitators in youth team sports.[81] In contrast, time constraints, lack of support and limited awareness of benefits are the main barriers to the dissemination and implementation of prevention WUPs.[81] This is in line with a qualitative study in which the perspectives of snow sports athletes on WUP were analysed.[9] Adherence to the WUP results from a process in which the positive effects of the WUP are experienced and lessons are learnt from one or more injuries.[9] Accordingly, educating athletes, coaches and other team staff on the role, effects and benefits of WUP&CD in enhancing performance and preventing injury and the concepts to consider is a cornerstone to increasing athlete adherence to warming up (**#149**). In this context, educational workshops that include supplementary resources may support implementation success.[81] Additionally, role models/testimonials are important for increasing athletes' compliance with WUP&CD (**#152**). The more people do it habitually and see it as an inherent part of competition and training, the more (younger) athletes may pick it up (**#140**).

Broadly implementing basic physical and psychological WUP activities at the youth level is an important measure to increase their overall adoption as an inherent part of training and competition.[9] In particular, (youth) athletes should be supported in experiencing the benefits of WUP, and WUP should be made a habit early on (**#155**). Institutionalised support is needed for young athletes to develop their individual WUP routines (**#145**). Moreover, coach engagement is considered important. Coaches need to know why WUP and activation are important (not only for injury prevention but also for performance) (**#150**).

Generally, snow sports athletes and staff acknowledge WUP as a complex and dynamic programme typically adapted to sport-specific demands, injury risks, environmental circumstances and individual needs and preferences.[9] Context-driven implementation plans can help athletes better adhere to WUP&CD (**#153**). A study assessing the experiences, beliefs and attitudes of injury prevention programmes in Danish youth handball players and coaches highlighted the lack of fun variation and benefit awareness as key factors hampering programme uptake.[82] This illustrates very well that youth athletes have different needs and preferences than elite athletes do, for whom a higher degree of individualisation, specificity and complexity is crucial.[9]

However, regardless of the context of application, keeping WUP&CD routines short and simple may increase athlete compliance (**#154**). As such, WUP&CD must be promoted and exemplified (**#140**). In addition, technology may help to better plan, implement and evaluate WUP&CD activities. Quantifying and documenting athletes' activation levels before the start, whether by subjective or objective measures, may provide valuable insights into the best way for individuals to warm up (**#158a**). Systematic athlete monitoring and data-driven decision-making have great potential to assist in developing meaningful WUP&CD activities in competitive alpine and freestyle skiers (**#159**). In practice, systematic athlete monitoring and data-driven decision-making, including WUP&CD activities, are severely limited by a lack of resources (financial, human, and infrastructure) (**#160**).

CONCLUSIONS

On the basis of this FIS consensus statement on WUP&CD before or after on-snow training and competitions, we provide guidance for competitive

alpine and freestyle skiers and snowboarders, coaches and medical staff of international and national federations and other entities that can promote and support appropriate WUP&CD practices in snow sports. In particular, youth competitive alpine and freestyle skiers and snowboarders should be aware of the benefits and familiarised with WUP&CD as early as possible to develop their individual WUP&CD routines towards the elite level. We hope that the current consensus-based WUP&CD best practice recommendations will help competitive alpine and freestyle skiers and snowboarders prepare and get ready for the high and diverse demands associated with sport participation and enhance their performance while protecting their health. Moreover, we hope that this consensus statement will stimulate further initiatives to fully address the WUP&CD in other snow sport disciplines such as cross-country skiing, ski jumping, Nordic combined, biathlon or ski mountaineering.

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