

Performance determinants in Ski mountaineering sprint: data from the pre-2026 Olympic test event

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Keywords: Ski Mountaineering, Sprint, Uphill, Transitions, Olympic Games.

Introduction

The Ski Mountaineering (SkiMo) sprint is a new winter Olympic discipline consisting of all-out effort with ski skins and poles of ≈2.5–3 min, raced in knock-out heats on a snow-covered terrain.

The course includes two uphill skiing sections (U1 and U3) separated by a very steep foot section (U2) and followed by a downhill skiing section to the finish (D) (Figure 1). Transitions (T) occur between sections to switch locomotion modes: the first (T1) involves placing the skis on the backpack to start the foot section, the second (T2) consists of putting the skis back on for the second uphill skiing section, and the third (T3) involves removing the skins and switching from an uphill to a downhill skiing setup.

At the international level, it has been shown that the U section plays a major role in explaining performance, with T being a secondary determinant, while downhill contributes only marginally (1). The aim of this study was to complete this knowledge by answering the following question:

What are the contributions of each race section to sprint time across different performance-level groups of international SkiMo athletes?



Figure 1: Sprint course and selected sections from the 2025 Milan-Cortina Olympic test event, identical to the course used at the 2026 winter Olympic games.

Methods

Milan-Cortina Olympic sprint Test Event 2025 (OSTE), part of the International Ski Mountaineering Federation (ISMF) WC, was analyzed. Total sprint time (SPT) and time spent in seven predefined race sections were quantified during the quarterfinals (QF). (Figure 1).

The first 36 men athletes according to the official time-trial qualification of OSTE were initially included (Figure 2). The top 18 athletes were assigned to the QF A and the next 18 to the QF B. To minimize potential motivational bias, only athletes who qualified for semi final (SF) in each QF were retained for analysis. Consequently, the final sample consisted of 24 athletes (12 from the QF A and 12 from the QF B).

- (1) An independent Student's t-test was used to analyze differences between QF A and QF B across the different sections when the assumptions of normality were met; otherwise, the Mann-Whitney U test was used.
- (2) The contribution of each race section to SPT variability was quantified as the covariance between section time and SPT relative to SPT variance, expressed as a percentage. Analyses were conducted separately for QF A, QF B. The temporal contribution of each section to SPT was also expressed as a percentage of total SPT (mean ± SD).
- (3) Associations between race sections and SPT were assessed using Pearson's or Spearman's correlations, depending on the data distribution, with Bonferroni correction for multiple comparisons.

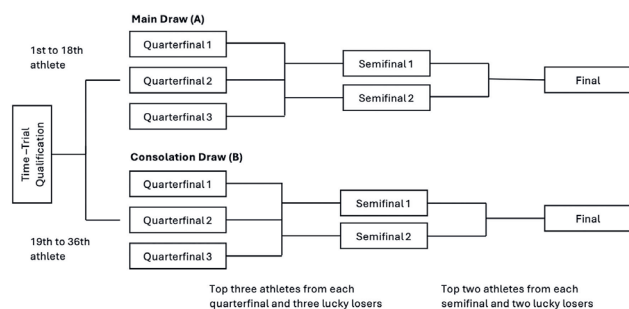


Figure 2: Milan-Cortina test event 2025 competition format.

Bibliography

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Results

(1) U, representing $60.1 \pm 1.4\%$ of SPT, is the only section that is statistically different between QF A and QF B. Transition (representing $18.9 \pm 1.1\%$ of SPT) and downhill (representing $20.5 \pm 0.9\%$ of SPT) are not significantly different between groups.

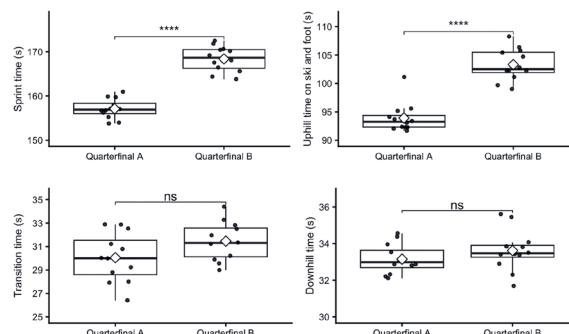


Figure 3: Box plot showing athlete variability by section and quarterfinal in 24 elite male ski mountaineering athletes who subsequently qualify for the semifinal. Total sprint time. Uphill time on ski and foot. Transition time. Downhill time. **** $P < 0.0001$, ns: not significant.

(2) T, representing less than a fifth of race time ($19.1 \pm 1.2\%$), explains almost half (46.8%) of the sprint time variability in QF A, among the world's best sprinters. It is 28 percentage points higher than in QF B.

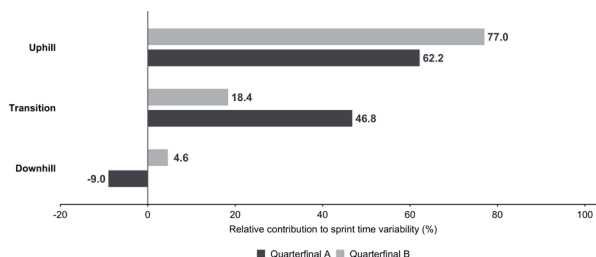


Figure 4: Relative contribution of race sections to sprint time variability during the quarterfinals in 24 elite male ski mountaineering athletes who subsequently qualify for the semi-final.

(3) U1 and T1 are associated with SPT while the other sections of the race were not.

Table 1: Time spent in the seven track sections during the quarterfinal and its correlation with SPT in 24 elite male ski mountaineering athletes who subsequently qualify for the semi-final.

Terrain	Track section	Technique	Time in section (s)	Correlation between section time and SPT
Uphill	U1	SU	76.51 ± 4.78	0.91****
	U2	FA	12.96 ± 0.85	0.48
	U3	SU	9.14 ± 0.78	0.44
	Total		98.62 ± 6.29	0.89****
Transition	T1	M1	9.21 ± 0.72	0.62*
	T2	M2	8.67 ± 0.79	0.13
	T3	M3	12.87 ± 1.23	0.33
	Total		30.75 ± 1.97	0.48
Downhill	D	DW	33.39 ± 0.98	0.22

U : Section involving uphill displacement; T : Section involving technical manipulation; SU : Skiing uphill movement; FA : Foot ascent with skis on the backpack; DW : Descent while skiing; M1 : putting the skis on the backpack; M2 : putting the skis on; M3 : taking skins off; SPT : Total sprint time in the quarterfinals. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, **** $P < 0.0001$

Conclusion: So What?

- (1) High importance of uphill time to explain ski mountaineering sprint performance
Uphill performance remains the entry ticket: Sprinters should develop their uphill performance to perform better in sprint formats.
- (2) Transition time contributed more to sprint performance among the world's top ski mountaineering sprinters
Among the world's best, fast and error-free transitions are an important distinguishing factor. Sprinters should consider transitions as an integral part of training.
- (3) Major performance differences appear to be established early in the race
Athletes who perform best in the early section of the race tend to achieve superior overall performance. It highlights the importance of this part of the race.