A WEARABLE SYSTEM TO MEASURE SPEED AND PHASE DURATIONS DURING EACH CYCLE OF CLASSICAL CROSS-COUNTRY SKIING

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INTRODUCTION: Analyzing speed and temporal characteristics is critical to understand the biomechanics and improve athlete performances in cross-country skiing. Currently, these analyses are mainly performed in research labs using heavy instrumentation and there is a need for simpler systems allowing measurement in natural environment. Furthermore, for optimal analyses, it is important to obtain data for each cycle independently and to have systems simple enough that they can be used without assistance during every-day practice. This study aimed to design and validate such a wearable device for the diagonal stride.

METHOD: The solution consisted of two inertial measurement units (Physilog®, CH) attached to the left ski and left pole, respectively. Using custom algorithms, relevant temporal features, e.g. cycle and thrust (leg and arm) durations, were automatically calculated based on the acceleration and angular velocity signals. Skiing speed was estimated by integration of the ski sensor acceleration and the use of biomechanical constraints of the diagonal stride. The system was first validated against a reference 3D camera-based system (VICON®, UK) with 10 athletes skiing on treadmill. Additionally, 13 athletes were measured while skiing on snow and analyses were performed to assess the sensitivity of the system to changes in skiing mechanics, including testing for relationships between speed and the phase durations using ANCOVA.

RESULTS: For all parameters, small errors were obtained when comparing the system to the reference (Table 1). The system detected strong associations between the three phase durations and skiing speed (Table 2).

Table 1: Validation against the reference, N=1200 cycles

	Parameter Range	Relative Error, Mean ± SD
Cycle speed	1.6 - 3.5m/s	0.2 ± 3%
Cycle duration	1179 - 1939ms	0.1 ± 0.8%
Leg thrust duration	60 - 408ms	1.7 ± 4.7%
Arm thrust duration	354 - 940ms	5.3 ± 4.9%

DISCUSSION: The indoor experiment showed the validity of the system and the measures on snow indicated that the system is sensitive enough to detect changes in skiing mechanics. While literature already suggested that cycle and thrust durations are speed-dependent (Stöggl, 2011), the system proposed in this study allowed confirming these relationships for athletes skiing in a natural environment. The resolution of the system was high, allowing investigating cycle-to-cycle variations. Importantly, the system is simple to use and can be set up by the athlete alone. It should be noted that the system additionally measures swing and recovery phases not discussed in this abstract for sake of consistency.

CONCLUSION: This study introduced a valid and sensitive system to measure the temporal signature and cycle speed of cross-skiing movement. The system has a high potential for professional and recreational applications as it can be used in any fields without assistance.

Table 2: Sensitivity to changes

		R^2	p
Speed vs. cycle duration	↘	0.93	<0.001
Speed vs. leg thrust	↘	0.92	<0.001
Speed vs. arm thrust	↘	0.94	<0.001

REFERENCES

Stöggl, T., et al. (2011). General strength and kinetics: fundamental to sprinting faster in cross country skiing? Scand J Med Sci Sports, 21, 791-803