Effect of a Fixed versus Dynamic Pitch on Hockey-Specific Skating Skills
A Comparative Analysis

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Defining Pitch: Pitch is the pivot point along the length of a skate blade that defines the angle between the blade and the ice *(Figure 1)*.

- **Fixed** pitch is a single pivot point, defined as backward, neutral, or forward.
- **Dynamic** pitch permits access to a range of pivot points to maximize blade-ice contact.

Purpose: To compare the kinematic and kinetic profiles of competitive hockey players executing hockey-specific skills when skating on two pitch conditions: **fixed** versus **dynamic**.

Study Design: A three-phased, multi-instrumentation investigation was conducted whereby geometry, kinematic, and kinetic data were collected and compared across two pitch conditions. Phase 1 mathematically modelled the geometry of the two pitch conditions. Phase 2 and 3 contrasted the kinematic and kinetic data collected while executing hockey-specific skills on two pitch conditions, in two skating environments. Phase 2 was conducted in-lab on a skating treadmill and Phase 3 in a real-sport environment, on-ice.

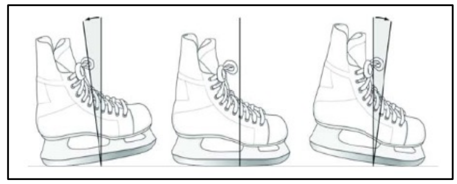

Figure 1. Illustrations of pitch: backward pitch (left), neutral pitch (middle), and forward pitch (right).

PHASE 1: MATHEMATICAL MODEL

A mathematical model and simulation compared the geometry of the **fixed** versus the **dynamic** pitch conditions to affirm the proof concept.

- Blade contour, referring to the length and shape of the blade, was modelled using an imaging system (*Figure 2*).
- The allowable range of pitch angles permitted by the **dynamic** condition was quantified and used to simulate the **dynamic** pitch mechanism (*Figure 3*).
- Three-dimensional kinematic data of the foot obtained from skating trials were used to define the orientation of the blade relative to the ice.
- The mathematical model determined contact point, contact length, and pitch angle throughout the skating stride to understand how the blade interacts with the ice as a result of a **dynamic** pitch (*Figure 4*).

Results of Phase 1 provided a mathematical model and simulation to define a **fixed** versus a **dynamic** pitch and specifically, contrasted the interaction of the pitch condition with the ice.

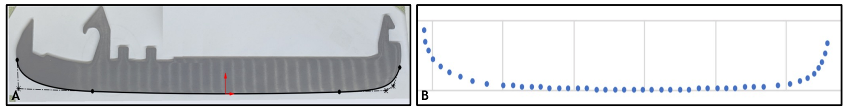

Figure 2. Modelling of a skate blade with a **dynamic** pitch for use in a mathematical model. (A) **dynamic** pitch blade, and (B) modelled contour.

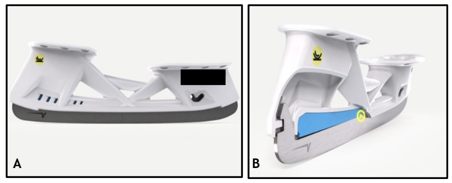

Figure 3. Illustrations of (A) dynamic pitch holder, (B) dynamic pitch mechanism

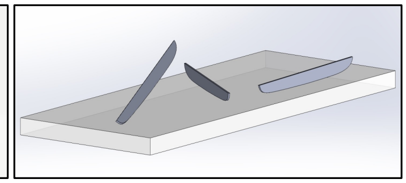

Figure 4. Blade orientation obtained through foot orientation.

METHODOLOGY: INSTRUMENTATION AND DATA PROCESSING

A multi-instrumentation approach was used to collect kinematic and kinetic data.

- Kinematic data were collected using an Inertial Measurement Unit (IMU) motion capture system (Xsens Awinda, Movella™, NV, USA) consisting of 17 wireless IMUs secured to the body to measure and describe stride mechanics, sampling at 60 Hz (*Figure 5)*. Lower body kinematics including hip, knee and ankle joint angles (deg) were collected.
- Kinetic data were collected using a wireless a plantar pressure insole system (X4 Foot and Gait Measurement System, XSENSOR® Technology Corporation, AB, Canada) to measure in-skate pressure (psi), sampling at 120 Hz (*Figure 6*).
- Kinematic and kinetic data were sectioned into individual strides by skill and time normalized. Data analyses on time normalized discrete kinematic and kinetic variables were performed (*Figure 7*).
- Principal component analyses (PCA) with single component reconstructions (SCR) were performed on time normalized 3D positional data (*Figure 8*) and on filtered pressure data.
- SCR waveforms were generated to illustrate temporal and magnitude differences between pitch conditions.

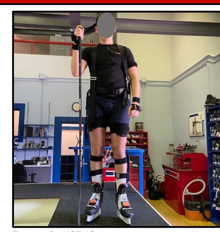

Figure 5. XSENS instrumentation (Xsens Awinda, Movella™, NV, USA)

Figure 6. XSENSOR pressure distribution insoles (XSENSOR® Technology Corporation, AB, Canada)

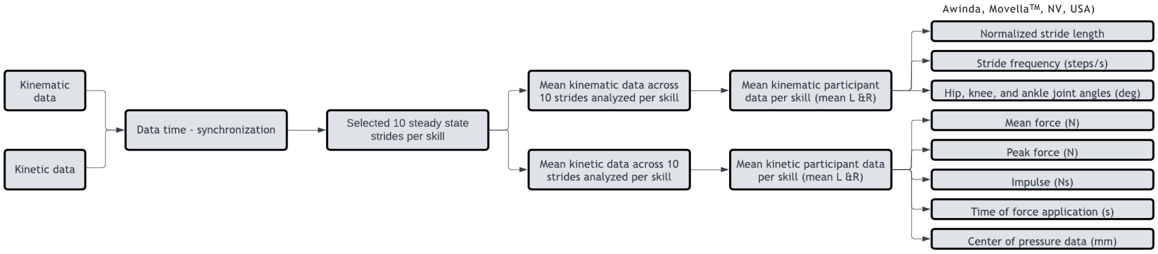

Figure 7. Data collection and analysis process. Kinematic and kinetic data were time synchronized and averaged across ten strides for each of the hockey-specific skills. Discrete kinematic and kinetic outcome measures were calculated.

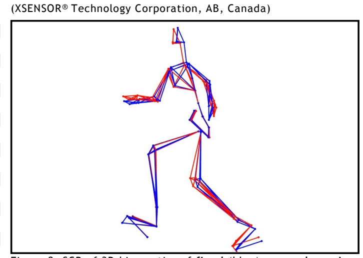

Figure 8. SCR of 3D kinematics of **fixed** (blue) versus **dynamic** (red) pitch conditions.

PHASE 2: KINEMATICS AND KINETICS IN-LAB

Phase 2 generated kinematic and kinetic profiles of male, collegiate level hockey players (n=11) executing hockey-specific skating skills on two pitch conditions (**fixed** versus **dynamic**), in-lab on a skating treadmill.

- Hockey-specific skills included forward skating, inclined forward skating, c-cuts, and backward skating.
- Both discrete (*Table 1*) and SCR (*Figure 9*) outcome measures were contrasted by pitch conditions.

Skills	Pitch Conditions	Normalized Stride Length (-)	Hip Angle (deg)	Knee Angle (deg)	Ankle Angle (deg)	Mean Force (N)	Peak Force (N)	Impulse (Ns)
Forward skating	Fixed	51.75	59.57	65.54	12.67	383.13	728.16	420.40
	Dynamic	51.95	59.87	65.07*	12.50	362.96	671.80	387.58
Inclined Forward Skating	Fixed	58.84	60.08	67.66	12.62	380.27	763.53	357.54
	Dynamic	57.72	60.59	67.56	12.45	358.01	719.59	332.62
C-cuts	Fixed	88.73	15.79	52.46	3.18	419.43	610.43	518.38
	Dynamic	90.90*	15.70	53.19	4.01	388.48	566.54	469.94
Backward Skating	Fixed	106.89	21.25	48.27	0.61	418.09	691.51	393.14
	Dynamic	110.05*	21.70	48.59	1.21*	397.84	660.18	373.04

Table 1. Discrete analysis results of all four hockey-specific skills of skating on two pitch conditions in-lab on a skating treadmill. * *sig*.

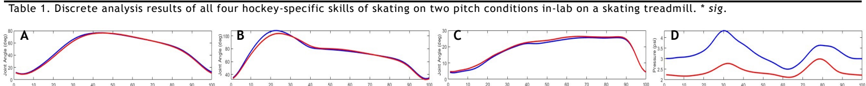

Figure 9. SCR of (A) hip flexion, (B) knee flexion, (C) ankle flexion, (D) pressure of forward skating of **fixed** (blue) versus **dynamic** (red) pitch conditions.

- Results of Phase 2 kinematics revealed larger normalized stride length (-) and mean joint angles (deg) when performing forward skating on the **fixed** versus the **dynamic** pitch, but smaller mean joint angles (deg) when performing c-cuts and backward skating on the **fixed** versus the **dynamic** pitch.
- Phase 2 kinetic results revealed greater mean force (N), peak force (N), and impulse (Ns) on the **fixed** versus the **dynamic** pitch, meaning that less force was require to maintain the same velocity.
- PCA and SCR revealed temporal and magnitude differences between the **fixed** versus the **dynamic** pitch.

PHASE 3: KINEMATICS AND KINETICS ON-ICE

Phase 3 generated kinematic and kinetic profiles of hockey-specific skills on **fixed** versus **dynamic** pitch conditions on-ice.

- Hockey-specific skills included forward skating, c-cuts, backward skating, agility turns.
- Skills were analyzed in isolation and in combination (*Figure 10*).
- Combination drills are representative of game play.
- Discrete outcome measures were contrasted by pitch conditions (Table 2).

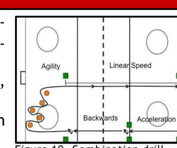

Figure 10. Combination drill.

Skills	Pitch Conditions	Stride Length (m)	Hip Angle (deg)	Knee Angle (deg)	Ankle Angle (deg)	Mean Force (N)	Peak Force (N)	Impulse (Ns)
Forward skating	Fixed	546.25	52.63	69.62	9.58	476.89	1136.33	363.46
	Dynamic	543.18	52.79	69.68	13.31	350.43	898.92	262.01
C-cuts	Fixed	978.82	13.58	57.80	0.36	462.32	883.37	460.58
	Dynamic	1029.1	12.64	61.56	0.07	351.10	500.26	301.99
Backward Skating	Fixed	1024.6	13.04	57.55	2.01	460.14	1009.40	325.84
	Dynamic	996.98	14.68	60.63	1.16	361.51	874.00	250.94
Agility Turns	Fixed	-	61.36	59.77	10.36	481.14	1196.44	2524.74
	Dynamic	-	63.81	60.96	8.74	351.95	915.27	1940.06

Table 2. Discrete analysis results of all four hockey-specific skills skating on two pitch conditions in a real-world environment on the ice.

- Results of Phase 3 kinematics revealed minimum variations between the two pitch conditions during forward skating; however, lower joint angles (deg) performing c-cuts, backward skating, and turning on **fixed** pitch compared to the **dynamic** pitch, consistent with the kinematic results of Phase 2.
- Phase 3 kinetic results were consistent with the kinetic results of Phase 2.

Conclusions: Outcomes of the three-phased and multi-instrumentation approach permitted both proof of concept and support for the contribution of a **dynamic** pitch to skating efficiency.

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