DOI Link: https://doi.org/10.61586/bOwGV
Vol.78, Issue.12, Part.1, Dec 2025, PP.17-29

Observation and Technical Analysis in Inline Speed Skating – Curve: Study Protocol

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Funding: This work was funded by National Funds by FCT - Foundation for Science and Technology under the following project UID/04045: Research Center in Sports Sciences, Health Sciences, and Human Development

Received Feb 2025 Accepted Nov 2025 Published Dec 2025

Abstract
Technique is a crucial factor in sports performance, particularly in inline speed skating. The main objective of this study is to analyze and compare behavioral patterns in two types of track curves: (i) curves with straight or direct inclination and (ii) curves with parabolic inclination. The study will focus on male skaters at the national and international levels, whose lap times in a flying start do not exceed 17 seconds. To conduct the research, an observation system will be developed, refined with expert input, and validated by experienced trainers. The methodology will include high-resolution video recordings and biomechanical analyses to assess the system's efficiency and practical applicability. Additionally, the developed system will be designed to be both accessible and adaptable, ensuring seamless integration into coaches' daily training routines. Three cameras will be used to capture video footage of the second curve in a 200-meter race. The expected results aim to identify technical differences and similarities between the two types of curves, providing precise and valuable data to optimize technical training. Through this study, we seek to rigorously and systematically establish the differences in skaters' performance across the different tracks curves.

Keywords: *Inline Speed Skating, Technical Analysis, Observational Methodology, Curve*

Introduction

Inline speed skating is a sport characterized by cyclical movements, primarily involving straight and curve techniques, with repetitive motions throughout each event—whether on the track or indoors, where tracks are symmetrical. Road circuits, on the other hand, are asymmetrical; however, the straight and curve techniques are still repeated based on the circuit's characteristics. In addition to these two techniques—straight and curved—the sliding technique is also utilized, depending on the curve's characteristics (greater or lesser amplitude) and the skater's conditions while skating it (speed and trajectory).

Speed skating coaches analyze the sport's technical aspects either on-site or through video footage, relying on their experience. O'Donaghue (2010), cited by Sousa, J. (2024), states that analyzing an athlete's performance by comparing it to a theoretical model is a fundamental tool for improvement. Given that technique is a crucial factor in a skater's performance—whether in competition or training—the use of indicators or criteria to characterize an athlete's technique can serve as a reference for coaching intervention (Gomez-Ruano et al., 2020).

A rigorous study and analysis of curves can provide coaches with essential data to enhance skaters' performance. Observing crossing and sliding techniques allows for the identification of key technical elements influencing a skater's motor performance in curves. Based on observational methodology, a system was developed to assess crossing and sliding techniques on curves.

Research and technical studies on inline speed skating are limited, with a greater number of studies focused on ice speed skating (Boer, 1987, 1987b, 1988, 1989; Koning, 1991; Hext, 2017; Song, 2018; Kruk, 2018; Kimura, 2024, among others). Boer (1987b) notes that there are similarities between inline and ice speed skating. Boer (1987) also states that, unlike straight sections of the track, stroke frequency—and consequently power production—cannot be freely adjusted by the skater in curves. As a result, differences in push-off mechanics are expected when skating curves. The same author, in 1988, explains that the power required to follow the curve trajectory depends on the skater's speed in the curve, the work per stroke, and the curve's radius (Boer, 1988). Koning (1991) observed that curve skating involves an asymmetrical leg movement pattern and that the skate follows a curved trajectory, which may significantly influence skating kinetics. The same author states that when skating a curve, an inertial force enables the skater to achieve higher extension moments and greater joint power during the push-off compared to straight-line strokes, particularly in the left stroke on a curve (Koning, 1991). Kruk (2018) investigated push-off forces using an instrumented short-track skate, while Kimura (2024) examined the trajectories within curves, including entry, exit, and the full curve.

The literature consulted includes studies on curve techniques in ice speed skating dating back to the 1970s (Marino, 1997; Boer, 1987, 1988; Koning, 1991). Song (2018), in the context of ice speed skating, proposed an analysis of the crossing technique by defining the following phases: (i) landing of the left skate, marking the beginning of the first crossing; (ii) loss of contact between the right skate and the ground; (iii) landing of the right skate; (iv) loss of contact between the left skate and the ground. Later, Kimura (2024) also analyzed crossing techniques in ice speed skating, identifying two phases: (i) the left skate push and (ii) the right skate push. Both phases were defined by the complete exit of the opposite skate blade and the complete exit of the pushing skate.

This study follows a theoretical model for crossing and sliding techniques based on empirical knowledge. The crossing technique is composed of the following phases: (i) landing of the left skate on the final step of the straight technique; (ii) end of the push and initiation of recovery of the right skate; (iii) crossing of the skates; (iv) landing of the right skate; (v) end of the left skate push; (vi) alignment of both knees in the sagittal plane. The sliding technique is characterized by the vertical and bilateral alignment of key reference points: (i) shoulders; (ii) hips; (iii) knees; (iv) skate tip.

Several authors have emphasized the use of systematic observation in scientific research. Anguera (2013) highlights the importance and utility of observational methodology in sports, while Cope (2022) considers systematic observation a valuable coaching development tool. Various studies have applied systematic observation in sports, such as Izquierdo C. (2021), who examined communication in sports; Gamero-Castillero (2022), who developed an observation tool for taekwondo; and Quiñones (2019), who created an observation system for handball. Despite the bibliographic research conducted, no studies or protocols based on observational methodology have been found for speed skating—either inline or on ice—that analyze sports performance throughout an entire curve. However, studies utilizing image recording for technical analysis do exist.

Regarding curve analysis, Juda (2007), in ice speed skating, conducted a technical study during a long-duration test. He concluded that the thigh angle during the sliding phase of the left lower limb impulse in the second half of the curve was greater than in the first half, and the center of mass was positioned further forward during the latter phase. Noordof, D. (2013), in the context of ice speed skating, analyzed the effectiveness of pushing in the straight technique, determining that the decrease in speed can be partially attributed to a reduction in push effectiveness, which reflects a decline in energy production associated with fatigue. The same author, in 2014, examined the relationship between technique and speed variation (Noordof, 2014), noting an association between technical effectiveness and speed fluctuation. Hext (2017) developed an image collection protocol for measuring relay times in short-track speed skating, focusing on the straight section of the track. His findings indicated that using a single camera is a valid method for measuring straight-line transmission times. Bu et al. (2017) designed an image processing structure for arbitration in speed slalom competitions within the freestyle discipline, concluding that the system was effective. Regarding inline speed skating, Bongiorno (2024), in a case study, conducted a kinematic and electromyographic analysis of the straight-line technique. Findings revealed that different speeds influence the overall distribution of muscle load.

In this sport, technique plays a crucial role in athletic performance, with the curve serving as the transition point between the straight technique pattern and the curve technique pattern. When skating the curves, skaters must adapt to several challenging factors, including: (i) forces generated by the curve, such as centripetal and centrifugal forces; (ii) the curve's inclination type; and (iii) the curve's amplitude. Given the importance of curve analysis in performance optimization—and considering the variety of inclined curve types—the technical insights derived from this study could be instrumental in an athlete's specialization. To this end, an observation system can provide coaches with rigor and objectivity in technical curve analysis, serving as a valuable tool for enhancing a skater's athletic development.

The aim of this study is to analyze and compare skaters' motor performance in two types of curves: (i) curves with straight or direct inclination and (ii) curves with parabolic inclination. To conduct the study, an observation system with clearly defined criteria will be employed to assess skaters' motor patterns.

Methodology

Sample

Participation and Selection Criteria

For the behavioral pattern analysis study, the sample will consist of skaters with a valid and up-to-date registration at their respective skating clubs. The inclusion and exclusion criteria are detailed in Table 1.

Table 1. Sample inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Male skaters	Female skaters
Junior and senior skaters	Skaters at levels below juniors and masters skaters
Skaters at least 17 years of age	Skaters under 17 years old
Skaters with at least 5 years of experience participating in national competitions	Skaters with little competitive experience, less than 5 years of participation in national competitions
Skaters with at least 1 year of experience in international competitions	Skaters without international competitive experience
Skaters who voluntarily apply to participate in the study	

Sample size

The study sample will consist of 20 male skaters, aged 17 to 27 years, who voluntarily agree to participate. After providing biographical data and undergoing anthropometric assessments, participants will proceed with the test. They will be instructed to follow their usual preparation and warm-up routines as they would in competition.

ISSN: 0004-0843

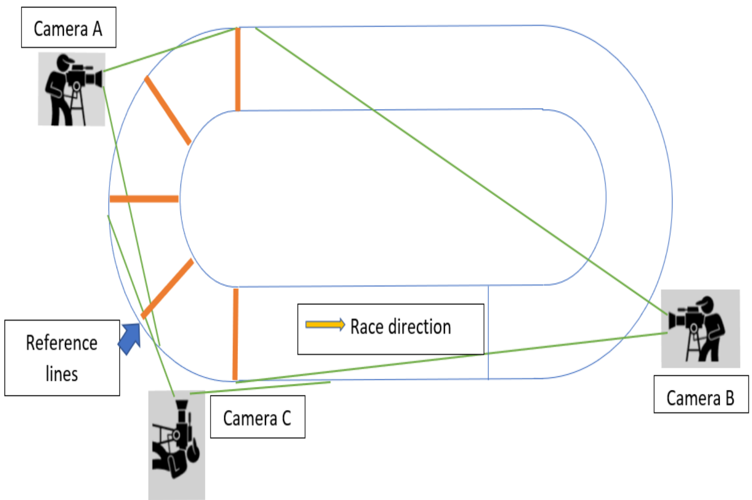
For this controlled one-group study conducted on two tracks, the Ethics Committee has approved the experimental design, study protocol, and consent process. All participants will sign a written consent form before taking part in the study.

A questionnaire will be completed to collect biographical information, and anthropometric assessments will be conducted. The test will be carried out under identical conditions—on the same track and within the same session—with video recordings made by the same researchers. The study will adhere to the ethical guidelines outlined in the "Declaration of Helsinki," as modified in 2000.

Experimental study design

A controlled study will be conducted with the same group on two tracks with distinct characteristics: (i) a track with a straight or direct inclination curve and (ii) a track with a parabolic inclination curve.
The experimental design will enable the observation of skaters’ technical and motor behaviors on each track. In addition to analyzing behavioral patterns, the time and distances covered in the curve will be measured using five reference lines (Figure 1), which will facilitate camera synchronization. Furthermore, the time spent sliding—if applicable—will be recorded.
Skaters will simulate a 200-meter competition: (i) the curve will begin when the skate lands just before the first crossover, and (ii) the curve will end when the skate lands on the final crossover.

Figure 1. Scheme with reference lines



To observe and record motor behaviors, a validated observation system will be used for both track types. The independent variables are as follows: (i) track with a straight inclination curve, (ii) track with a parabolic inclination curve, and (iii) observation moments on the curve, including respective conduct criteria and aggregated criteria.
To capture images, two cameras—A and B—will be positioned 60 meters apart, while a third camera, C, will be placed 55 meters from camera B and 28 meters from camera A. The tripod height for each camera will be 1 meter and 80 centimeters.

Procedures
The data collection process will take place on two inline speed skating tracks: (i) a track with a parabolic inclination curve and (ii) a track with a direct inclination curve. Four sessions will be scheduled for data collection.

Before the official data collection begins, a pilot study will be conducted to ensure the accurate placement of the cameras. Collaborators will receive instructions to ensure that, during the study, procedures align with the intended methodology and that camera operators fully understand how, when, and what to film.

Procedures in the organization
After recruiting participants, the inclusion criteria will be verified. A briefing will be held with the skaters and their accompanying personnel to explain the organization of the session and address any questions that may arise. A biographical questionnaire will be administered, and anthropometric data will be collected. Participants will be informed about the activity and will sign a consent declaration. The list of biographical and anthropometric data is provided in Table 2.

Table 2. List of biographical and anthropometric data

Biographical Data	Anthropometric Data
Name	Weight
Date of birth	Height
Gender	Body Mass Index (BMI)
Club	Body fat mass index (BMI)
Years of skating practice	
Participation in International tournaments	
Participation in national championships	
Participation in European championships	
Participation in world championships	
Time achieved in the one flying lap race (200 meters) last season	

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Skaters will complete their usual warm-up routine for this type of event, after which they will be ranked in descending order based on their official event times of this race. A designated individual will be responsible for organizing the track and calling skaters to participate in the race.

Each skater's lap time will be measured using a stopwatch and recorded manually. A timekeeper will oversee the timing, while another individual will be responsible for documenting the recorded times.

Procedures for capturing images

Each of the three cameras will be configured to capture high-speed movement at 60 FPS (frames per second). Support tripods will be used for all cameras, which will be powered through electrical extensions.

Two cameras will be positioned at the initial apex of each curve, while the third camera will be placed on a perpendicular line to the maximum internal apex of the curve, as illustrated in Figure 1. The three cameras will record the entire launched lap, ensuring the skater remains within the width of the track.

Instruments

The qualitative observational methodology will be applied in a natural context, closely resembling competitive reality (Anguera et al., 2000). Given the methodology used, it is essential to validate an observation system that enables the collection of the necessary data for this analysis (Oliveira et al., 2001).

Building upon the instrument developed by Medeiros, L. and Louro, H. (2013), a new system will be adapted to suit the study's objectives and validated for identifying skaters' motor patterns.

The observation system consists of six moments and 45 criteria. The conduct criterion focuses on the lower limbs, while the aggregate criteria include the trunk, head, upper limb segments, and the skater's total inclination. The first moment comprises 13 observation criteria, the second moment 5, the third moment 3, the fourth moment 11, the fifth moment 7, and the sixth moment 6.

To collect images, two SONY Mini-DV cameras and one CASIO Exilim camera will be used for recording. The footage will be saved onto the hard drive of a Lenovo laptop (AMD Ryzen 5 3500U with Radeon Vega Mobile Gfx, 2.10 GHz). The VirtualDub software will be utilized for viewing the images and recording occurrences for each criterion.

For the sequential analysis of motor patterns, the Theme 5.0 software will be employed (Magnusson, 2000; Magnusson et al., 2004; Campaniço et al., 2006; Anguera et al., 2007; Louro et al., 2009).

Weight and body fat index (BMI) measurements will be conducted using a bioimpedance scale.

Observation System

The bibliographic research identified an instrument designed and validated for observing behavioral patterns when skating curves (Medeiros, L. & Louro, H., 2013). This instrument is validated for analyzing only the first three crossovers and is applicable to both straight-inclination tracks and flat-curved tracks.

For this study, an adapted observation system based on the aforementioned instrument will be utilized.

Sample for validation of the observation instrument

For the validation process of the observation system, the following criteria will be used for the inclusion of coaches:

Table 3. Inclusion and exclusion criteria for coaches

Inclusion Criteria	Exclusion Criteria
Coaches with a level II or higher course, certified by the respective national skating federation and/or by World Skate.	Coaches with a level I coaching course or without a course
Coaching junior and/or senior skaters for at least 5 years	Coaches who have not had junior and/or senior athletes in the last 5 years
Coaches with at least 5 years of experience	Coaches with less than 5 years of experience
Coaches whose athletes have participated in at least 3 different international tournaments	Coaches whose athletes have participated in less than 3 different international tournaments

Inclusion Criteria	Exclusion Criteria
Coaches with a level II or higher course, certified by the respective national skating federation and/or by World Skate.	Coaches with a level I coaching course or without a course
Coaching junior and/or senior skaters for at least 5 years	Coaches who have not had junior and/or senior athletes in the last 5 years
Coaches with at least 5 years of experience	Coaches with less than 5 years of experience
Coaches whose athletes have participated in at least 3 different international tournaments	Coaches whose athletes have participated in less than 3 different international tournaments

Statistical Analysis

To compare sample data, categories will be calculated using inter-rater agreement probability values. To determine accuracy, data from the expert and the observers will be analyzed. The results will be evaluated by criterion using Cohen's Kappa concordance test index. GSEQ 5.0 software will be used to measure agreement within each criterion category (Cohen, 1960, 1968; Anguera, 1993).

Theme 5.0 is a software that utilizes the T-Patterns test to detect existing behavioral patterns (Magnusson, 2000; Magnusson et al., 2004; Anguera et al., 2007). T-pattern analysis includes all patterns, assessing the number of coded events, their occurrence, length, frequency, structure, skater identity, and behavioral content (Magnusson, 2000, 2004).

To validate the observation system, the methodology proposed by Aiken, L. (1985) will be applied, as it has been used in other studies, such as Sousa, J. (2022).

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