A Technological Approach to Performance Analysis in Competitive Street Skateboarding

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ABSTRACT

Street skateboarding made its Olympic debut at the Tokyo 2020 Games and is now part of the core Olympic program. The sport's rapid evolution, combined with its inherently subjective and freestyle nature has resulted in limited clarity around what constitutes performance and resulting outcomes. The overarching aim of this thesis was to use technological approaches to identify what constitutes successful performance in competitive skateboarding. The thesis comprised four sections: 1) understanding current knowledge and perspectives – **'drop in'**; 2) developing methods to objectively describe performance – **'get set'**; 3) applying methods to characterise and distinguish success – **'send it'**; and 4) translating findings into practice – **'land bolts'**. A scoping review of the literature (n=19 studies) identified physical and technical demands but revealed lacking understanding of what drives success in judged competition formats. This ambiguity was confirmed from the findings of a survey of sponsored Olympic (n=4, 25.5±2.89 years old) and amateur competitive skaters (n=10, 25.8±12.21 years old) which highlighted the need for clearer performance evaluation criteria. Style was rated as the top contributor to success, however the importance of its underlying objective aspects (e.g., speed, power) varied by skill-level and discipline. To obtain an objective understanding of such criteria, a notational analysis framework was developed leveraging publicly available broadcast footage, and used to capture trick, obstacle, and execution elements of trick attempts (TA) during best-trick (BT) and runs (RUN) from the Tokyo 2020 Games. Frames involving obstacle interactions were less reliable (mean absolute difference (MAD): intra=2.04-2.26, inter=3.62-4.35 frames). Take-off (MAD: intra=1.43, inter=3.32) and landing (MAD: intra=1.33, inter=1.55) frames could be reliably identified, particularly by an experienced rater. This objective method was applied to characterise and compare actions during the men's and women's competition. Men's scores were greater than the women's (β=1.71-1.85, $p<0.001$)

and descriptively more variable; men demonstrated greater trick selection whilst women displayed mostly regular stance grind tricks, notably in RUNs. How these differences were reflected in judge preferences, overall competition outcome, and where training should be focused, was explored using several linear regression models to determine which factors contributed to score differences. RUN models (R_M^2: M=0.750, W=0.829) were better fit than BT for both divisions (R_M^2: M=0.302, W=0.520). Using larger, feature obstacles was related to scoring in BTs ($\beta_{W\text{-}BT}$=0.86, $p_{W\text{-}BT}$<0.001); all BTs in the men's division used feature obstacles. Successful women distinguished themselves by flipping their board ($\beta_{W\text{-}BT}$=1.10, $p_{W\text{-}BT}$<0.001) and varying take-off stances ($\beta_{W\text{-}BT}$=1.10, $p_{W\text{-}BT}$=0.002); whereas successful men introduced uniqueness by combining tricks ($\beta_{M\text{-}BT}$=1.38, $p_{M\text{-}BT}$<0.001). In RUNs, there appeared a sweet spot number of TAs (β_{RUN}=3.67 to 4.58, p_{RUN}<0.001; 8 to 9) for a high score, albeit dictated by a quality-quantity trade-off possibly leading to the negative, non-linear relationship (β_{RUN}=-2.00 to 1.65, p_{RUN}<0.001). Bails were also critical; RUN scores decreased with each bail (β_{RUN}=-0.39 to 0.40, p_{RUN}<0.001). The findings from this thesis encompass the first objective understanding of skateboarding performance. Although more insights as to how these findings transfer across competitions is warranted, coaches can leverage the foundational performance model presented to focus training efforts and competition planning within the evolving landscape of Olympic street skateboarding.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

COMMON ABBREVIATIONS

AMT	Amateur
AVG	Average
BA	Bland-Altman
BS	Back-Side
BT	Best-Trick
CI	Confidence Interval
COMP	Competitive
DIR	Direction
DOM	Dominant
FS	Front-Side
IA	Interaction
ICC	Intra-class Correlation Coefficient
KPI	Key Performance Indicator
LD	Landing
LMM	Linear Mixed Model
MAD	Mean Absolute Difference
MOD	Modified
NA	Notational Analysis
OBST	Obstacle
PA	Performance Analysis
REC	Recreational
RUN	Run
SD	Standard Deviation
TA	Trick Attempt
TO	Take-off
WS	World Skate

ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except here explicitly defined in the acknowledgements), nor used artificial intelligence tools or generative artificial intelligence tools (unless it is clearly stated, and referenced, along with the purpose of use), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

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CO-AUTHORED WORKS

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Diewald SN, Neville J, Cronin JB, Read D, Cross MR. Skating into the Unknown: Scoping the Physical, Technical, and Tactical Demands of Competitive Skateboarding. *Sports Medicine.* 2024; 54: 1399-1418.

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INDUSTRY PRESENTATIONS

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DECLARATION OF COLLABORATION

Chapters 2 to 6 of this thesis represent separate papers that have either been published or will be submitted to peer-reviewed journals for consideration for publication. My contribution and the contribution by various co-authors to each of these papers are outlined below. All co-authors have approved the inclusion of the joint work in this doctoral thesis. Moreover, by signing below, we confirm that the co-author contributions stated in the table are accurate.

Student Name	Shelley Diewald	**Signature**		**Date**	19 May 2025
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–Dermot Kennedy

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Ethics approval for the relevant experimental work in this thesis research was granted by the Auckland University of Technology Ethics Committee (AUTEC) on 01 November 2022 for a period of three years:

- AUTEC #22/248 – "Defining skateboarding performance success: A community perspective" for Chapter 3 (Appendix I)

Other experimental chapters in this thesis leverage open and public access data, and did not involve recruitment. Consequently, no ethics approval for these specific works (Chapter 2, and Chapter 4 to Chapter 7) was needed.

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During the preparation of this thesis, generative AI (ChatGPT) was used to assist with proof-reading for grammatical purposes. All content generated through this tool was critically reviewed and revised to ensure accuracy and originality. No content was copied without substantial oversight or modification.

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CHAPTER 1:

INTRODUCTION

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1.1 Overview

California surfers created skateboarding in the 1950s when there were no waves, attempting to mimic wave riding on concrete [1]. Over the following decades, skateboarding proliferated as a popular grassroots sport, possessing strong values of freedom and self-expression, resisting authority and structure. ‘Success’ relied heavily on ‘being spotted’ by sponsors with disparate preferences, without a formalised global standard to judge performance. Nevertheless, various forms of competition were introduced over time, culminating in skating being included in the Olympics in 2020. Thus, skateboarding was thrust into legitimisation at the highest level, without substantial performance pathways, training strategies, or even coaches [2].

In 2010, only a decade before Olympic inclusion, Ryan Sheckler hired the “world’s first skate coach” [3]. Despite coaching in skateboarding long being considered “taboo” [4], increased funding opportunities meant competitive skaters were now working with coaches to keep up with the pressures to perform. Yet, the rapid transition from a commercialised leisure activity to a legitimate sport resulted in a lack of scientific literature to support the coaching process [5]. A brief appreciation of the history of skateboarding and its evolution will provide context to identify and explain disproportionate knowledge gaps in the literature.

1.2 History of Skateboarding

The history of skateboarding revolves around equipment development, benefitting different movement preferences and “styles” of skateboarding. The polyurethane wheels and various board (deck) widths and lengths led to the development of skateboarding disciplines (e.g., street, park, vert, downhill, longboard, etc.). Following the invention of the shortboard, skateboarders could “pop” specifically designed kicktails [6], causing the board and the skater to jump off the ground, otherwise known as an ollie [7]. Deck design and increased durability allowed skaters to take their skills to the streets, where they performed tricks using obstacles found in the urban environment. Specifically, street skateboarding combines elements from all other disciplines (park, “vert”, bowl, etc.) and is widely considered the most fundamental and versatile skateboarding discipline.

The growing popularity of street skateboarding drove the development of purpose-built parks, which provided skaters with a designated place to showcase their style whilst still resembling aspects of the street environment. This evolution has led to the emergence of a subculture, which represents an anti-authority movement valuing personal freedom and self-expression [8]. Many identify with the communities’ unique leisure values, dress codes, musical styles, and movement expressions. Community growth saw corporations and industries rush to capitalise on the skateboarding identity, with brands initially capturing the sport's cultural essence, eventually extending into the performance market [9].

1.2.1 History of Competition

Competitive skateboarding became popular in the United States in the 1980s, with associated business and capital investment. Accordingly, many skateboarders participated in contests seeking recognition and sponsorships [7]. In 1995, skateboarding gained global attention with the initiation of the X-Games, with the Skateboarding Street and Park series subsequently introduced to the Olympics [5]. Despite several decades of global street skateboarding competitions, formats and rules varied greatly depending on the event organiser, and as such, ‘performance’ was difficult to define. In an attempt to standardise the sport globally, World Skate was established [10].

1.2.2 World Skate

World Skate are responsible for any Olympic and Olympic qualifying events [10]. Importantly, the organisation decides the competition formats, scoring rules, and criteria used to define street and park performance, respectively. Accordingly, World Skate defined the competition rules for men's and women's skateboarding at the Tokyo 2020 Olympic Games and continues to be the international governing body for the now mandatory Olympic sport.

1.2.2.1 Competition Formats and Scoring

Qualifying and Olympic skateboarding competitions are organised into rounds; typically encompassing an open qualifier, quarter-final, semi-final, and final. At the Olympic Games, there are only semi-final and final rounds. Within each round, each skater performs in front of a panel of judges who score the skater's attempts. Depending on the discipline and format of the competition round, a mix of these scores are added together to form a skater's round score total, determining which skaters will progress to the next round. In all round formats, skaters either perform runs (RUN) or single best-trick (BT) attempts. During a RUN, an athlete links a sequence of tricks around the skatepark during a set time limit, flowing through the environment, utilising obstacles. Park competition formats only include run attempt types; however, street competition formats also typically include BT attempts. During BT attempts, a skater attempts a single trick, usually their most difficult and impressive. Another key difference between disciplines is what determines the end of a RUN. In street, RUNs terminate with the time set; a skater can dismount their board, either through a bail (not land) or deliberately, until the time expires. In park, a RUN is terminated when the skater comes off the board, usually in a bail, regardless of the time remaining. For the Tokyo Olympic Debut campaign, World Skate used a "2/5/4" format for street competitions and a "3/1" or "2/1" run format for park competitions. After Tokyo and leading into the Paris and Los Angeles Games, the street competition instead adopted a "2/5/3" format. These formats define the attempt types, how many attempts each skater gets, and which attempt scores are aggregated to result in a skater's total score for the round. The "2/5/4" and "2/5/3" street formats translate so a skater has "2" RUN attempts, "5" BT attempts, and the highest "3" or "4" of those attempt scores are summed. Moreover, a key difference between the formats was introduced, where at least one RUN attempt score must be included in the total round score. Originally, a skater's total round score could encompass BT scores, exclusively. During park competitions, a skater's highest RUN score also serves as their final round score. Despite formats and scoring differing between disciplines, presumably the criteria by which performance is judged does not.

1.2.3 Judging Criteria

At the Olympic debut, attempt scores were awarded on a scale from 0.00 to 10.00 points, however, like competition formats, the sport evolved to using a 0.00 to 100.00 point scale for subsequent Olympic campaigns. For each RUN or BT attempt, the judging panel uses a set of criteria to guide and award a score based on the overall impression of an athlete's performance within the parameters of the competition (overall impression score). The World Skate Judging Criteria was created to 'foster and preserve the progression of skateboarding while highlighting the importance of creativity and originality of skateboarding in a competition environment' and were defined as 'results of the values, principles, and virtues generally share and accepted by the skateboarding communities around the world' [11].

There are many other Olympic freestyle sports where expert judges score performance of participants, like gymnastics, diving, and figure skating [12]; however, in all of these sports, judges follow a set of guidelines to align their scores to a set of standards. In skateboarding, an athlete's final overall score during a round is simply used to rank the athletes. Additionally, unlike traditional aesthetic sports (e.g. gymnastics), the scoring is based on that competition round only. Therefore, although rank can directly be compared across rounds and competitions (e.g., 2nd vs. 3rd), absolute scoring cannot (e.g., 8.5 vs. 10). An athlete could perform the same trick in a competition's semi-final and final, yet be awarded a completely different score. Furthermore, judging does not rank in terms of past individual performances or potential ability, but ranks skaters against the global field of tricks and their execution [13]. Therefore, a thorough understanding of the criteria for ranking skateboarding athletes is crucial to comparing performances between rounds and competitions. The criteria used to formulate overall impression attempt scores include 1) difficulty and variety of performed tricks, 2) execution, 3) use of course and individual obstacles, 4) flow and consistency, and 5) repetition. Difficulty and variety of tricks is further broken down into obstacle selection, trick selection, originality, and innovation. Moreover, execution encompasses quality and 'style', which is further defined by a range of subjective and objective definitions set forth by World Skate, as presented in Table 1.

Table 1: Subjective and objective elements of style World Skate judging criterion

Subjective[a]		**Objective**[a]	
Fluidity	A SUBJECTIVE element of STYLE referring to the ease by which an athlete executes the tricks. Fluidity will be subjective to each judge.	Speed	An OBJECTIVE element of STYLE referring to how fast an athlete is going while executing a trick, run, or jam session.
Power	No definition provided	Height	OBJECTIVE measure of STYLE referring to how far off the ground or obstacle an athlete executes a trick / how tall an obstacle is
Aggression	A SUBJECTIVE element of STYLE referring to bold, forceful, assertive, energetic skateboarding. Aggression will be subjective to each judge	Distance	An OBJECTIVE element of STYLE referring to how far an athlete travels while executing a trick, be it a grind, a slide, a manual, an air, an ollie, a flip trick, etc.
Aesthetics	A SUBJECTIVE element of STYLE and how a trick looks when executed. For example, foot placement, how the feet catch the skateboard or arm movements. An aesthetically good trick is well executed and pleasing to the eye. Aesthetics will be subjective criteria for each judge	Quality of Landing	No definition provided

[a] 'Subjective' and 'objective' are terms used by World Skate to categorise and describe aspects of style criterion [11]

1.2.3.1 Style

Despite style measures that are perceived and defined by World Skate as objective (e.g., height), the criteria used for ranking are subjective. Judges' are inherently biased, likely leading to ambiguity and potential community misalignment on what aspects of performance lead to a high score [14]. Moreover, the degree to which the skateboarding community themselves understand what factors lead to success is broadly unknown [15], despite the fact that the World Skate Criteria are said to represent characteristics of performance valued by the community. This ambiguity makes performances difficult to compare and generally affects the ability to make physical, technical, and tactical training decisions.

1.3 Skateboarding 'Performance'

One confounding issue is that all athletes, regardless of division (Men's vs. Women's), compete on the same course and obstacles, and are scored on the same scale and criteria [13]. Moreover, round scores in the women's division of an Olympic street competition tend to be much lower than their counterparts (e.g., the Tokyo 2020 Olympics 10.04±4.06 (W) vs. 27.73±9.02 (M), respectively). The same holds true for park skateboarding (49.69±8.75 (W) vs. 73.41±21.17 (M)) (accessed from https://www.olympics.com/en/olympic-games/tokyo-2020/results/skateboarding/ on 01 April 2025). Whilst the issue remains as to what exactly constitutes these performance differences, it appears much of what impacts competition success, such as judging criteria and environment, is heavily geared toward the male population. Accordingly, understanding what factors represent success across and within the divisions, and whether mismatches exist between community perspectives of performance, is crucial to targeted and effective coaching practices.

Coaches play a critical role in enhancing athletes' performance by evaluating, intervening, and providing feedback throughout the training and performance cycle [4]. An informed perspective of how well an elite skater performs, and which factors underlie said performance, is critical to the ongoing development of the competitive aspect of a sport. In traditional Olympic sports, winning is relatively unambiguous, such as the number of goals or the first to cross a finish line. Performance can then be broken down into characteristics that underlie the ability to achieve that goal, such as maximal acceleration, and training can be balanced to improve various physical and technical parameters based on the individual athlete's strengths and weaknesses. However, without a clear appreciation of what it takes to perform at the highest level, coaches only speculate as to the determinants of success, potentially providing unreliable and inaccurate information. From this it can be inferred that an objective definition of competition success in skateboarding is needed to promote fairness, agreement, and transparency when judging a "good" performance. This would also aid coaches in decision-making for training and competition preparation.

Skateboarding is a complex activity that likely relies on a variety of factors [16]. Despite little research on the subject, we can assume by drawing from other sports, like surfing, that performance depends on an interaction of physiological, psychological, technical, and tactical factors [17]. The body of scientific literature regarding skateboarding is growing, yet competitive skateboarding performance is a relatively underexplored research topic. Notably, whilst there is a large body of literature on skateboarding injury epidemiology [18-20], none specifically addresses injury causes, occurrence, recovery, or aspects of skill. Identifying skateboarding key performance indicators (KPIs) and underlying demands would help practitioners develop contextualised training to both enhance performance and perhaps reduce injury risk.

Researchers have investigated technical [21, 22] and physiological [23-27] components of skateboarding. Yet, these efforts appear fragmented and lack integration into a cohesive understanding of competitive performance. Moreover, no study has systematically linked these demands to competition outcomes. As a result, the field lacks a clear consensus or framework by which to guide the understanding of skateboarding performance. This gap underscores the need to synthesize and evaluate the current knowledge and perceptions of competitive skateboarding performance across physical, technical, and tactical domains to leverage learnings which can be implemented into coaching practices. This knowledge would direct future research efforts towards steps to address any critical gaps in the literature pertaining to an objective assessment of competitive performance.

1.4 Performance Analysis

Performance analysis (PA) is the investigation of sports performances to develop an objective understanding to inform decision-making, enhance performance, and inform the coaching process [28]. Typically, it involves incorporating tactical and technical evaluation, movement analysis, and developing predictive models to enhance an athlete's chances of winning. Practitioners utilise various technologies and statistical approaches to identify and measure KPIs that are associated with competitive success [29, 30]. No PA in skateboarding has been conducted, and therefore, there is no defined framework by which to consistently describe aspects of performance.

Since the sport is heavily influenced by its counter-cultural history and values, skateboarding PA should appreciate and reflect the subjective needs of the community, without hindering the skater's freedom of expression or movement [31]. Luckily, knowledge and methodologies from sports possessing similar values to skateboarding (e.g., freestyle board sports) could guide such PA, like snowboarding and surfing [32-34]. Both snowboarding and surfing feature a degree of subjectivity, and performance is related to "flow" and "creativity" of movement on their board through the environment. Structured and unstructured video acquisition and analysis is commonly used to understand aspects of performance, often self-recording for reflective PA and content sharing [4], to understand both surfing [33, 35-38] and snowboarding [34, 39]. Feasibly, knowledge and PA techniques from more established subjective sports, such as standardised diving and gymnastics, in addition to freestyle board sports surfing and snowboarding, could be leveraged to develop methods to objectively understand skateboarding performances.

1.4.1 Notational Analysis

A widely used method within PA is notational analysis (NA), which involves the systematic observation, coding, and quantification of key performance elements. NA enables practitioners to objectively evaluate both technical and tactical components of performance by characterising complex sporting movements in a valid and consistent objective manner [40]. This is particularly important in sports like skateboarding, where subjectivity in judging can obscure patterns of performance. NA encompasses many forms like scoring analysis, time-motion analysis, and technical-tactical characterisation [41] and is often used in combination with other methods such as biomechanical or statistical modelling to understand underlying aspects of performance [42]. In freestyle board sports, where aesthetic and creative elements are valued, NA provides a bridge between the subjective nature of performance and the objective need to measure and improve it.

NA is a crucial tool in identifying patterns and events associated with success in judged sports [43]. One proven application of NA is the specific use of video coding to retrospectively decompose judges' scores using statistical techniques to obtain KPIs [44]. This approach has proven valuable in aesthetically driven sports [32, 34], offering a precedent for its application in skateboarding. In diving, video NA was used to obtain objective metrics (dive entry angle) to compare with judges scores within and between competitions [12]. A similar application of NA in surfing revealed that including aerial manoeuvres during competition significantly improved judging outcomes [32]. Similarly, in snowboarding NA was used to link increased jump rotation and airtime to higher run scores, and highlight the importance of the last jump during a snowboarding slopestyle run for overall impression score [34, 45]. Importantly, findings from the aforementioned studies demonstrate how NA can illuminate the relative contribution of specific technical elements, such as rotation direction, non-dominant take-off stances, or trick sequencing, to overall performance scores. Moreover, the application of video-based NA techniques for different attempt types, single trick attempts or consecutive trick attempts, further demonstrates the potential for its application to decompose ambiguous 'overall impression' scoring in Olympic skateboarding to guide coaching interventions and athlete preparations. Although some fundamental skateboarding trick metrics derived from video were found to be valid in a controlled setting [22, 46, 47], the sport has yet to adopt such technologies in competition. Therefore, developing and validating a NA process to conduct standardised PA in skateboarding is warranted, and would enable the ability to objectively understand different attempt types, and to explore discipline and sex differences that may exist.

1.5 Thesis Rationale

The rapid development of skateboarding into an Olympic level sport, in addition to an informal culture, have likely driven the current lack of understanding regarding performance. Existing research is limited, predominantly focused on injury surveillance or the biomechanics of isolated tricks, and lacks a broader investigation into performance in competitive settings. Furthermore, there is an absence of comparative analyses across sex or discipline, and no consensus on methodological approaches to evaluating performance within freestyle board sports more broadly.

Competitive street skateboarding is judged subjectively, based on criteria such as trick difficulty, style, and execution. Whilst these elements are central to the identity of skateboarding, they are inherently ambiguous and influenced by personal and cultural perceptions. This ambiguity represents a challenge in comparing performance within and between athletes. Nonetheless, these subjective criteria are underpinned by measurable physical attributes. For example, jump height may enhance style, or speed may provide access to more complex tricks. As such, there is an opportunity to quantify performance-relevant aspects of style and develop objective frameworks that align with subjective judging standards.

PA offers a methodological lens through which sport performance can be examined, modelled, and targeted via training. PA has been widely applied in traditional and emerging sports to inform coaching, decision-making, and talent development. However, its application to skateboarding remains underexplored. Given the unique aesthetic and individualistic nature of the sport, traditional win-oriented PA approaches may be inappropriate. Instead, bespoke frameworks that reflect the sport's values and judging criteria whilst enabling systematic analysis are most likely required.

This thesis aimed to address this gap by developing and applying a PA framework specific to competitive street skateboarding. Drawing on technological methods, including NA, video analysis, and statistical modelling, the thesis seeks to identify KPIs associated with competitive success. It further aims to provide coaches and athletes with actionable insights to support training and performance preparation. Importantly, this work is conducted in collaboration with national stakeholders including Skateboarding New Zealand and High Performance Sport New Zealand, ensuring both academic rigour and practical relevance. Moreover, international collaborations enable the capturing of new Olympic populations.

The findings of this thesis are intended to advance the field of PA in freestyle board sports, contribute to the legitimisation of skateboarding as an Olympic discipline, and support the development of the next generation of elite skateboarders.

1.6 Research Aim and Questions

The objective of this thesis was to identify what constitutes a successful performance in competitive skateboarding. The following broad research questions were developed to be answered in specific chapters in the aim of addressing this overarching objective:

1. What are the known physical, technical, and tactical demands of competitive skateboarding based on the current literature?
2. How do skaters and community members perceive success in competitive skateboarding, and what are the implications for performance evaluation and training?
    a. Do perceptions of success differ by discipline (street vs. park), skill level (amateur vs. professional), or level of community involvement (competitive vs. recreational)?
3. Can a NA framework be developed to reliably describe key components of street skateboarding performance?
    a. To what extent can this framework capture aspects of flow and style that are influential in judging outcomes?
4. What are the defining characteristics of elite performance in Olympic street skateboarding?
5. How do performance strategies and scoring patterns differ between the men's and women's street competition?
    a. Which objective performance metrics best predict success in RUN and BT attempts?

1.7 Research Design

To address the research questions listed above, a variety of research designs were adopted, largely within a quantitative framework:

1. In Chapter 2, a systematic scoping review was undertaken to critique the current literature on skateboarding performance, focusing on the physiological, biomechanical, technical, and tactical demands.

2. In Chapter 3, a cross-sectional study, which constituted largely descriptive and correlational analyses, via an online survey, was used to explore the understanding of skateboarding performance within the athlete community, focusing on how skaters perceived the criteria used to evaluate their performance and guide their training.

3. In Chapter 4, a methodological and reliability study (featuring repeated measures) was performed, which focused on the development and testing of a custom NA framework and application for analysing street skateboarding performance. The study design included quantifying intra- and inter-rater reliability of measuring spatio-temporal metrics from broadcast footage.

4. In Chapter 5, a descriptive-comparative NA design was used to objectively classify, describe, and compare performance characteristics and attempt scores between the men's and women's street skateboarding Olympic debut.

5. In Chapter 6, to identify and explore associations between performance characteristics and scores, a cross-sectional analysis was adopted utilising NA and linear mixed-effects modelling on RUN and BT attempts from the men's and women's Olympic debut.

1.8 Thesis Originality

Broadly, this thesis contributes original research to a significantly underexplored area, competitive skateboarding. As a newly introduced Olympic sport, skateboarding has received limited academic attention to date, particularly in relation to competition analysis and performance evaluation. Nevertheless, skateboarding as an activity itself is well established, with very strong cultural views, in which the opposing systematic, quantified, and structured approach directly conflicts with the typical values of the community. This research is an original undertaking, with a novel systematic approach in a freestyle sport, but a critical step at an opportune moment to provide the competitive community with methods to characterise and understand performance to train and reduce injury effectively. Specifically, underexplored areas of research include:

- Competitive skateboarding performance and its underlying demands.
- Aspects of performance within specific populations; including, street skaters, female skaters, and Olympic skaters.
- In the field of freestyle board sports, methods by which to reliably classify and quantify performance aspects typically judged subjectively.
- Objective description of skateboarding competitions.
- The use of systematic and applied technological approaches to explore performance indicators in freestyle board sports to explain judges scores.

This research is not only academically original, but practically valuable. It offers a foundation that can support Olympic-level athletes and aspiring skaters by providing actional insights into the factors that underpin competitive skateboarding success.

1.9 Thesis Structure

This thesis was conducted using quantitative research methodology to address the overarching aim and answer the underlying research questions, comprising a series of chapters each written in the format of a published scientific journal article (i.e., 'Pathway Two' thesis via Auckland University of Technology). As such, repetition of some information (e.g., introduction, research methods, discussion points) inevitably occurs, given each chapter is written to be understood in isolation from that surrounding it. Preludes have been included to provide links and practical applications between chapters.

The associated reference for each respective journal article is provided at the beginning of each chapter, and the full published article (if applicable) is available in Appendix II. Chapters 1 through 8 are divided into four thematic sections outlined in Figure 1.

Section One, ***'Drop In'***, much like a skater dropping in to start their trick (or run), initiates the direction of the PhD by providing an overview of skateboarding performance. This section includes the introduction, scoping literature review, and cross-sectional survey. The introductory chapter provides the rationale for the research, originality, and structure of the thesis, whilst introducing key themes that recur throughout, including the transition of skateboarding from a subculture to a sport, the need for objective performance understanding, the role of technology and systematic methods, judging subjectivity, sex-based differences, and the practical application of findings. Chapter 2 is a systematic review of the literature pertaining to the physical, technical, and tactical demands of skateboarding. Then in Chapter 3, a survey of the skateboarding community provides perspectives of elite and amateur competitive skaters on performance criteria and the importance to competition and recreational success. Survey participants include international Olympic street and park skaters, as well as New Zealand domestic amateur, Olympic hopefuls.

Section Two, ***'Get Set'***, represents a skater's lead up into a big trick; setting their speed and position, the skater mentally and physically prepares for the trick they are about to attempt. This section lays the essential framework by which the overarching aim of this PhD can be addressed. This research is the first to develop and test a systematic framework to classify and quantify aspects of freestyle, subjectively judged board sports. The design process of the framework and the custom NA application used to apply it are described in detail.

Section Three, ***'Send it'***, represents the peak moment when a skater pops their board to leave the ground; stylishly rotating and flipping their body and board attempting a trick. This section includes Chapters 5 and 6, which utilise the method developed in Section Two to address which objective performance metrics best predict success in RUN and BT attempts. In Chapter 5, the technical demands of the Olympic debut of street skateboarding are described, comparing the men's and women's divisions. The performance characteristics quantified in Chapter 5, and their relative contribution towards judge-awarded attempt scores are investigated in Chapter 6 by utilising statistical approaches like mixed effect models.

The final section, Section Four, ***'Land Bolts'*** signifies the conclusion of a skater's trick; landing the trick perfectly, with both feet squarely on the bolts which hold the trucks to the deck; like sticking the landing in gymnastics. Likewise, this section, comprising Chapter 7 and Chapter 8, aims to strongly conclude the PhD providing an overall summary and practical applications of the thesis findings. Specifically, Chapter 7 is a commentary on practical applications and recommendations resulting from thesis findings, providing a 'picture of performance' for competitive street skateboarding. Chapter 8 then concludes and summarises the overall outcomes. Without this section, the PhD would feel incomplete, much like a bailed trick. It plays a crucial role in guiding future research direction and ensuring the findings can be applied in practice.

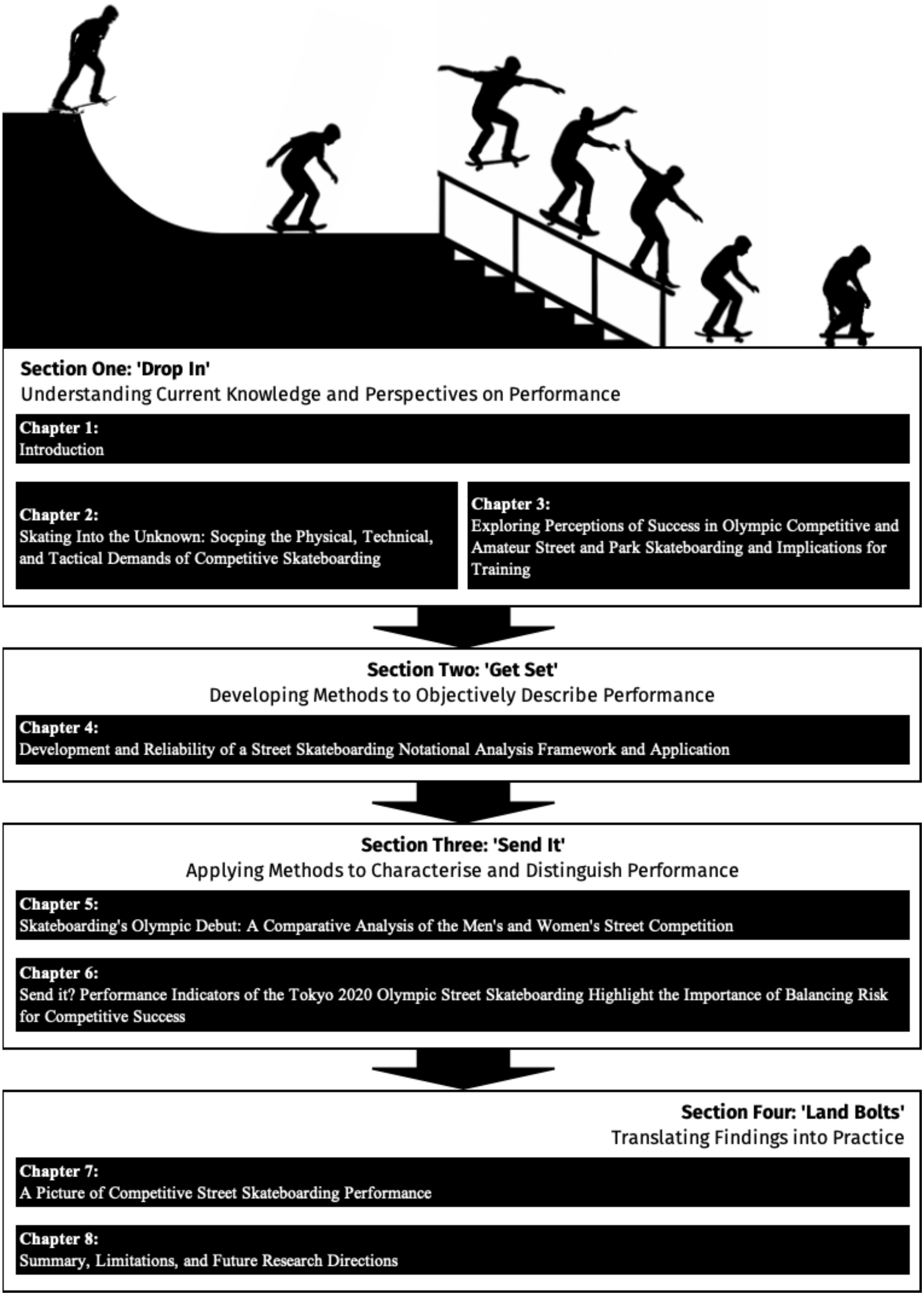
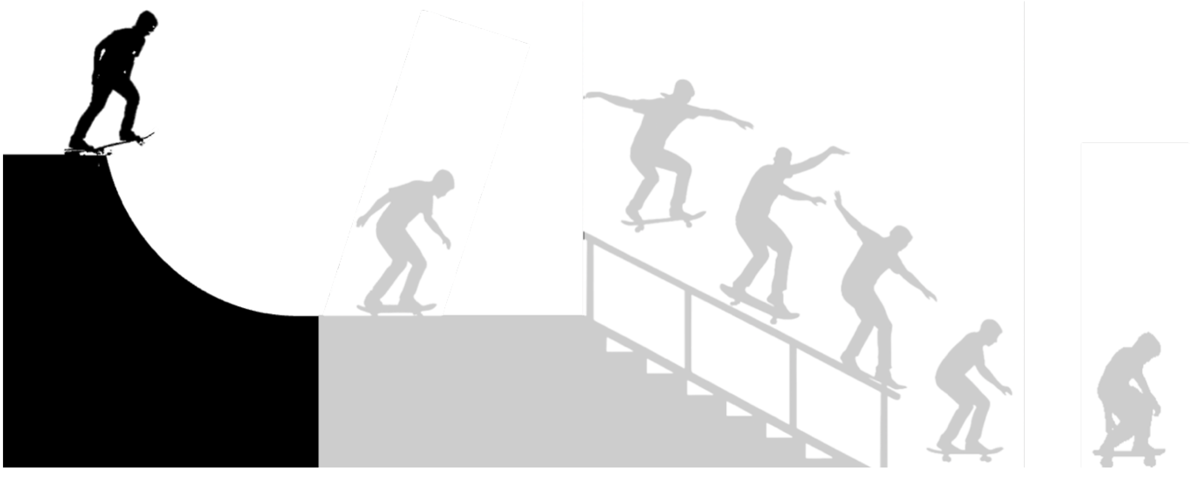


Figure 1: Overall thesis structure

SECTION 1: 'DROP IN'

UNDERSTANDING CURRENT KNOWLEDGE AND PERSPECTIVES ON PERFORMANCE



CHAPTER 2:

SKATING INTO THE UNKNOWN: SCOPING THE PHYSICAL, TECHNICAL, AND TACTICAL DEMANDS OF COMPETITIVE SKATEBOARDING

This chapter comprises the following paper published in the *Sports Medicine* journal:

Diewald, S. N., Neville, J., Cronin, J. B., Read, D., & Cross, M. R. (2024). Skating into the unknown: Scoping the physical, technical, and tactical demands of competitive skateboarding. *Sports Medicine*, 54. https://doi.org/10.1007/s40279-024-02032-1

Prelude:

Understanding the current knowledge base on competitive skateboarding performance forms the foundation of the thesis and guides the direction of important steps and questions to be addressed in the proceeding chapters. At the outset, no review existed, and the few published data appear primarily constrained to non-competitive populations. In Chapter 2, therefore, the physical, technical, and tactical demands of competitive skateboarding are explored. To achieve these goals, a systematic scoping review was conducted to provide a holistic overview of the literature, synthesizing the available evidence on skateboarding performance. This review also identified knowledge gaps, providing important information for guiding forthcoming chapters of the thesis, and ultimately guidance for practitioners and Olympic-hopeful skaters.

CHAPTER 2: SKATING INTO THE UNKNOWN: SCOPING THE PHYSICAL, TECHNICAL, AND TACTICAL DEMANDS OF COMPETITIVE SKATEBOARDING

2.1 Introduction

In an attempt to mimic wave riding on concrete in the 1950s [1], California surfers created skateboarding, which soon spread as a popular grassroots sport [48]. In 1995, skateboarding gained global mainstream attention with the initiation of the X-Games, leading to its debut at the Olympic Games in Tokyo 2020 [48]. It was subsequently approved for Paris 2024 and Los Angeles 2028 [49]. Skateboarding is one of the fastest-growing sports in the world, with over 50 million people skating globally [2]. These numbers will likely increase with an influx of young athletes seeking to follow the Olympic pathway [50] and succeed on the world stage [51]. To support coaches and athletes in decision-making for training and competition preparation, it is essential to identify key performance indicators (KPIs) and underlying determinants that align with competition success [52].

Olympic skateboarding has two disciplines, "street" and "park" [48], with unique formats and associated judging criteria [13]. In park, athletes perform 2 or 3, 45-second runs in which they link a sequence of coping (rail) and aerial tricks together in a "bowl" course [48]. Runs are terminated at any point the skater comes off of the skateboard (i.e., "bails") [53]. In street, skaters perform isolated tricks on an obstacle (best-trick) and/or a sequence of tricks linked together around the entire skatepark (run), using the kick-push (locomotion with one foot swinging and contacting the ground to propel forward and the other supporting leg on the board) to regulate horizontal speed [53]. In both street and park, tricks can be attempted in various stances ("regular", "goofy, "switch", "fakie", "nollie") while travelling and rotating either frontside (FS) or backside (BS), and flipping and rotating the board along various axes [54], interacting with obstacles in the environment to create individualised styles [55, 56].

Competitive skateboarding performance is defined by judges, utilising criteria [13] to subjectively rank athletes on their ability to land tricks. The principles employed by judges to compare and rank performances within a given Olympic-qualifying competition round are 1) trick difficulty and variety, 2) execution, 3) use of course and obstacles, 4) flow and consistency, and 5) repetition [13]. The difficulty and variety of performed tricks include obstacle selection, trick selection, and originality and innovation [13]. Common ways of potentially increasing the trick difficulty (and associated score) include performing tricks in different stances (riding "switch", where the skateboarder rides in the non-preferred stance), linking different variations of tricks (flip trick into a grind), and increasing the height, length, and speed of movement [57]. Although some of these criteria likely have an objective basis through which performance might be targeted and improved (e.g., increased velocity of trick entry) [58], judging ultimately occurs through a subjective lens [13]. So, the relative importance of these factors to creating a good score (i.e., performing well) is a-priori unclear.

Drawing from other similar freestyle, subjectively-judged, skill-based sports possessing a more substantive body of research (e.g., surfing and snowboarding), we can assume that skateboarding performance depends on an interaction of objective physical, technical, and tactical factors [17, 59]. Within these sports, understanding of these factors is important in providing a basis of empirical data from which to direct training [60], examine athlete progression [59, 61], and enhance athlete performance [62]. Nonetheless, no review on the topic exists, and such information would be best placed in tandem to a thorough understanding of what makes an athlete perform well in-situ. A literature review is a critical first step in assessing the current state of the research to determine the most effective path forward to provide practitioners and athletes with objective, evidence-based support to compete at the highest level. To our knowledge, a synthesis of the demands of skateboarding has yet to be conducted.

So, this research aims to evaluate the physical, technical, and tactical demands of competitive skateboarding. It is important to first establish the KPIs of competitive skateboarding, focusing on neuromuscular, physiological, and biomechanical factors essential for high-level performance. A scoping review was selected for this purpose, with the aim of providing a holistic overview of the literature that synthesizes the current evidence on skateboarding performance and qualities, highlights knowledge gaps, and provides guidance for practitioners and future researchers.

2.2 Methods

2.2.1 Protocol

This study identified and mapped the current literature on the physical, biomechanical, technical, and tactical demands of competitive skateboarding. The conduct of the scoping review was informed by Arksey and O'Malley's six stage methodological framework [63], with the protocol conducted according to the Joanna Briggs Institute (JBI) methodology for scoping reviews [64] and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Extension for Scoping Reviews: Checklist and Explanation [65]. The final protocol was registered with the Open Science Framework (Registration Number: 10.17605/OSF.IO/Z94WT).

2.2.2 Eligibility Criteria

The population, concept, and context (PCC) of interest were defined to form the inclusion criteria [64]. Table 2 presents the final inclusion and exclusion criteria.

Any populations participating in skateboarding were included, except "longboarders", "electric skateboarders", "hoverboarders", and "disabled populations". No age, sex, or skill level restrictions were imposed. Trick-based competitive disciplines, "park", "bowl", "street", "vert", and "freestyle", were included due to the potential relevance to Olympic disciplines (park and street). We excluded non-trick-based skateboarding ("longboarding", "downhill") [56].

Excluding the technological (e.g., equipment) and social demands of skateboarding, research regarding the physical, technical, and tactical demands was included to focus on objective determinants of competitive performance. Cross-sectional and longitudinal studies were included. Only studies that utilised actual participants (skateboarders) were included, with explicitly mechanistic studies (e.g., mathematical modelling of the skateboard/rider system) were excluded.

Table 2: Criteria for inclusion and exclusion in the scoping review

Inclusion Criteria	Exclusion Criteria
• Participants are skateboarders • Any competitive, trick-based disciplines ("street", "park", "bowl", "surf", "vert", "free-style") • Address physical, technical, and/or tactical demands of skateboarding • All ages, sex, and levels of skill • Acute and longitudinal study designs • English text available • Published peer-reviewed literature (including conference proceedings and theses) • All study designs • After 1970	• Participants are "longboarders" (or "downhill"), electric skateboarders, hoverboarders, or any other skating sport (figure skating, roller skating, speed skating) • Skateboarding for commuting purposes • Social aspects of skateboarding • Environmental aspects of skateboarding • Mathematical/mechanical modelling of skateboarding (including robotics) • Injury focused studies • Non-peer-reviewed (magazines, government documents, conference abstracts) • No full text available (after attempted communication with the author)

2.2.3 Information Sources

Databases were the primary information sources. The search was conducted in MEDLINE (Ovid), Scopus, SPORTDiscus, and PubMed on 20 January 2022 by the primary author (SD). An updated search was conducted on 3 May 2023, and three additional articles were identified, with one included in the review. Google Scholar was also searched in Incognito mode following the database search for relevant articles [66], and the first 200 titles and abstracts were reviewed for relevance and inclusion. All published information sources after 1970, including full-text theses and conference proceedings, were included.

2.2.4 Search Strategy

The search strategy was guided by the preferred PRISMA recommendations [67] and aimed to locate published peer-reviewed literature. The primary author (SD) conducted an initial limited search in Google Scholar to identify articles on the topic. Keywords were identified for potential inclusion and exclusion criteria. Inclusion and exclusion criteria were then developed by the primary (SD) and secondary authors (MC) during the preliminary search and refined before conducting the final scoping review search. The search strategy and Boolean phrases were adapted for each included database and secondary source (Table 3).

Table 3: Search databases and associated search strings

Database	Search String
Scopus	Skateboard* [Title, Abstract, and Keywords]
SPORTDiscus	Skateboard* [Title, Abstract, and Keywords]
MEDLINE (Ovid)	Skateboard* [Title, Abstract, and Keywords]
PubMed	"skateboard*"[All Fields]
Google Scholar (Secondary Source)	Intitle: skateboard OR intitle: skateboarding OR intitle: skateboarder

2.2.5 Study Selection

Articles were selected per the PRISMA-ScR statement [65], and a modified PRISMA 2020 flow diagram was created to depict the search process. Search results were exported into EndNote [68]. Following duplicate removal, the EndNote library was imported into Rayyan [69] for further screening. The primary author (SD) screened titles for relevance and eligibility.

During this stage, articles were removed if they did not relate to the population of interest (e.g., ice, ice hockey, cross country, skating, speed skating, hockey, inline skating, roller skating, cells/animals/soil, carbon monoxide), focused on skateboarding injuries, or were the wrong publication type (magazines, government documents, etc.). The abstracts of the remaining articles were then screened for relevance independently by the primary (SD) and secondary author (MC). Literature were then removed using the exclusion criteria in Table 2. The reference list of articles meeting full eligibility criteria were also screened and examined for additional relevant data and inclusion in the scoping review, termed "snowballing" [70]. Finally, the remaining abstracts were extracted, full-text articles were reviewed independently by the primary (SD) and secondary authors (MC) and the exclusion criteria were further applied. All disagreements were resolved immediately during this process, and any excluded full-text records and associated reasoning were reported.

2.2.6 Data Extraction

The JBI Methodology Guidance for Scoping Reviews was initially utilised to frame the data charting process [66]. The data extraction chart created was an iterative process conducted by the primary author (SD). Key areas of interest, outcome measures, results, and overall findings were identified.

2.2.7 Critical Analysis and Reporting

The results and discussion sections include an initial descriptive narrative overview of the studies and their relevant findings. A frequency analysis was conducted to provide a numerical summary of the nature, extent, and distribution of the included studies (Tidyverse package (version 1.3.2) in R Statistical Software (RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/). Key variables coded to characterise research on demands of competitive skateboarding were publication year and type, study design, study tools, population, and associated demands. Where possible, quantitative results were compared across studies with similar methodologies and subgroups: demand types (physical, technical, and tactical), participation experience level (recreational vs. competitive), and competition level (amateur vs. professional).

Specifically, the technical demands of skateboarding reported were separated by utilising the 2021 World Skate judging criteria [13]. The difficulty and variety of performed tricks include obstacle selection, trick selection, and originality and innovation. Execution is defined as how well a trick is performed from start to finish. This criterion is further broken down into the quality of trick execution and style of execution, defined by World Skate as: "A distinctive manner or appearance by which a trick is executed, how a skater looks when they do a trick, or how a trick looks when executed. Every skateboarder's style is unique, and some elements of style (aesthetics, aggression, fluidity, and power) will be subjective to each judge." [13]. World Skate definitions of style elements are presented below in Table 4. According to PRISMA Best practice guidance and reporting items for the development of scoping review protocols [64], unlike traditional systematic reviews, scoping reviews do not typically include a step for the assessment of the methodological quality or risk of bias of sources of evidence. Thus, no risk of bias assessment on individual studies was conducted [63, 71].

Table 4: Definitions of objective and subjective elements of style within World Skate skateboarding judging criteria

Subjective[a]		**Objective**[a]	
Fluidity	A SUBJECTIVE element of STYLE referring to ease by which an athlete executes tricks. Fluidity will be subjective to each judge.	Speed	An OBJECTIVE element of STYLE referring to how fast an athlete is going while executing a trick, run, or jam session.
Power	*No definition provided*	Height	An OBJECTIVE measure of STYLE referring to how far off the ground or obstacle an athlete executes a trick / how tall an obstacle is
Aggression	A SUBJECTIVE element of STYLE referring to bold, forceful, assertive, energetic skateboarding. Aggression will be subjective to each judge	Distance	An OBJECTIVE element of STYLE referring to how far an athlete travels while executing a trick, be it a grind, slide, manual, air, ollie, flip trick, etc.
Aesthetics	A SUBJECTIVE element of STYLE and how a trick looks when executed. For example, foot placement, how the feet catch the skateboard or arm movements. An aesthetically good trick is well executed and pleasing to the eye. Aesthetics will be subjective criteria for each judge in both disciplines.	Quality of Landing	*No definition provided*

[a] 'Subjective' and 'objective' are as defined by World Skate, and do not reflect the technical definitions of subjective and objective criteria [13]. All judging in skateboarding competitions is via a subjective lens.

2.3 Results

2.3.1 Frequency Analysis

2.3.1.1 Overview

A total of 4979 articles were identified with the search strategy. After 544 duplicates were removed and title screen exclusion criteria were applied, 257 abstracts remained for screening. An additional 3 studies were identified from the reference list of articles meeting full eligibility criteria. The final title and abstract screening left 30 relevant full-text articles. Two separate authors reviewed the full-text articles (SD and MC), identifying 18 appropriate studies utilising the exclusion criteria in Table 2. Following the updated search in May 2023, a single additional article was included, resulting in 19 studies for inclusion in the final analysis (Table 5). Articles assessing the physiological (n=9), biomechanical (n=8), and technical (n=10) demands of skateboarding were found, however tactical demands for competitive skateboarding were not analysed in any included research. Moreover, competitive skateboarders were used as participants (n=3), but the remaining research did not specify participant competition history.

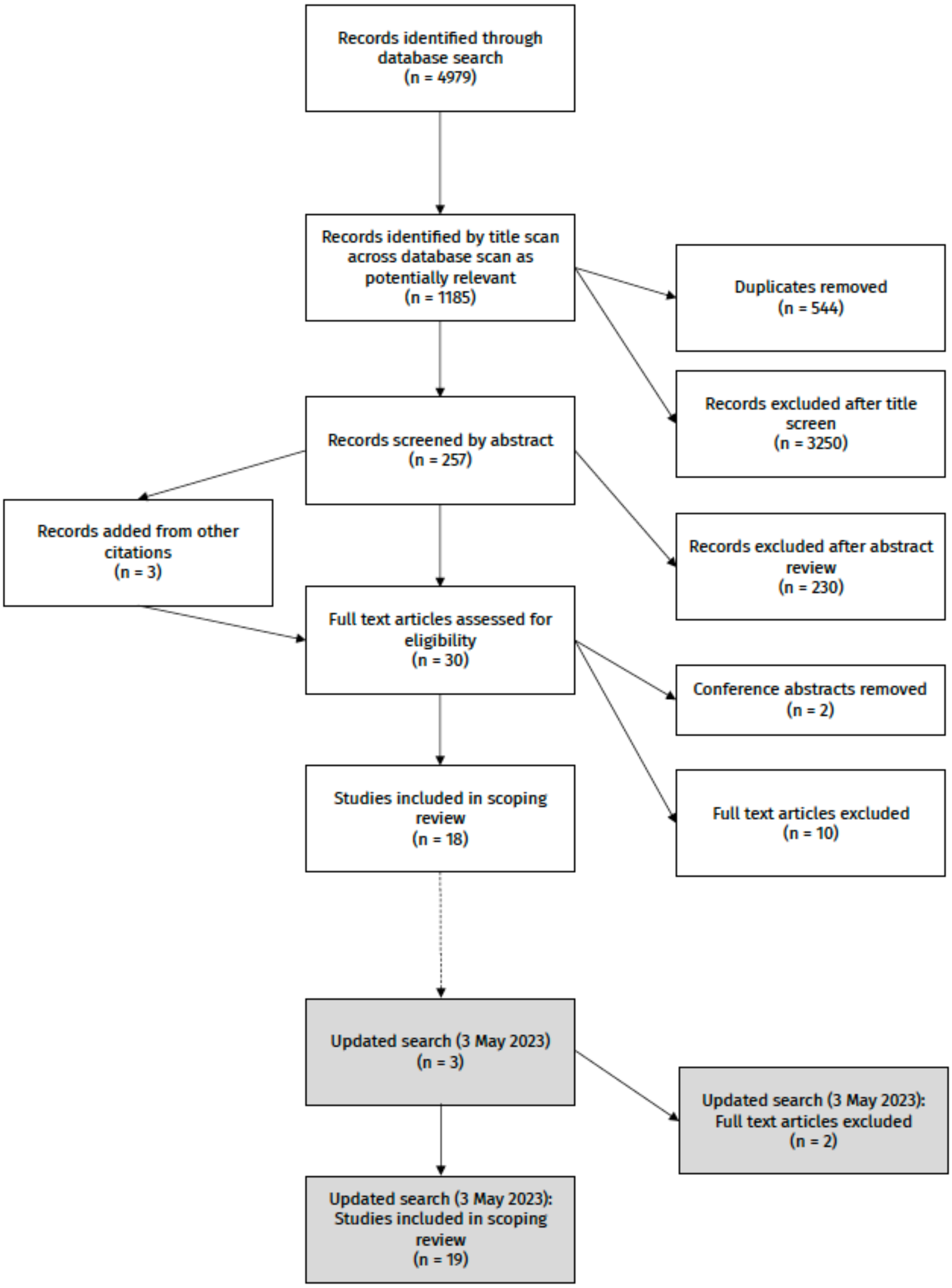


Figure 2: Flowchart of study selection process regarding skateboarding performance.

Table 5: Scoping review included studies with participant details, study aim, publication details, relative demands, and study outcomes

Reference[a]	Participant details (number, sex, inclusion criteria and/or experience)	Study aim	Publication details (type, year) Study design Study location Field-based, (Field), laboratory-based (Lab)	Demands[b]			Outcomes (author main findings)
				Biomechanical	Physiological	Technical	
Nessler, Lundquist [72]	N=30 adult skaters "with > 6 months of experience" 10 males (BIPOC only); experience (years): 17.4±11.8 20 females (19 BIPOC); experience (years): 4.3±4.9	Measure and compare heart rate response and activity in female skaters, BIPOC skaters, and non-skaters for 1-hour sessions at skatepark	Journal article (2023) CS, CORR Field		X		Session time (females only): Moving=57% session Stationary 1-10 s=5% Stationary 11-60 s=18% Stationary 1-3 min=12% Stationary > 3 min=8% Average female HR=138.4±12.0 bpm Horizontal and vertical (elevation) distances travelled significantly greater for males than females and non-skaters
Clark, Bishop [73]	N=12 male recreational skaters "with > 10 years of experience"	Investigate relationships between asymmetries, subjective skateboarding performance, and objective jump performances in skateboarders	Journal article (2021) CS, CORR Lab		X		SJ Asymmetry=20.5±10.9% CMJ Asymmetry=13.6±9.3% DJ Asymmetry=20.2±16.4% Subjective performance ranking positively correlated with SJ asymmetry, but not CMJ or DJ
Furr, Nessler [74]	N=71 youth skaters "with > 1 year of experience" 63 males, 8 females; experience (years): 3.0±2.3	Characterise intensity and duration of youth skateboarders at community skateparks	Journal article (2021) CS, DESC Field		X		Youth recreational skateboarders at community skateparks meet governmental recommendations for exercise and resemble high-intensity interval training
Ou, Chen [75]	N=32 amateur and professional skaters "with > 3 years of experience"	Investigate ankle joint movement of professional and amateur skateboarders	Journal article (2021) CS, CORR Lab		X		Inversion dominant ankle ROM of professionals is significantly less than

	N=16 professionals (full-time skateboarders with corporate sponsorships) (1 female, 15 males) N=16 amateur (no titles from competitions) (1 female, 15 males)						amateurs. No difference in muscle reaction time
Rasid, Kamarudin [76]	N=1 male amateur skater “with 5 years of experience”	Identify skateboarding tricks that could be used to identify amateur skaters	Conference proceeding (2021) CS, CORR Lab			X	Ollie and nollie tricks could be suitable for identifying amateur-level skateboarders
Nakashima and Chida [21]	N=1 male recreational skater “with 2 years of experience”	Use simulation to understand ollie mechanics and forces between rider’s feet and board	Journal article (2021) CS, SIM Lab	X		X	To maximise ollie height, a skater must produce sufficiently fast rotational movement around rear wheels, by separating both feet from deck before tail of deck hits ground (pull up front foot early and fast) and separate rear foot from deck (to not contact deck after pop)
Pietta-Dias, Ruas [77]	N=11 male professional street skaters (experience level not specified)	Measure knee side-to-side strength asymmetry and compare hamstring:quadricep ratios between limbs of professional street skateboarders	Journal article (2020) CS, DESC Lab		X		No between-limb differences in isometric or isokinetic knee strength. Skaters had weak eccentric hamstring strength relative to quadricep strength
Wiles, Kellogg [78]	N=45 adult skaters “with > 1 year of experience” 44 males, 1 female; experience (years): 3.0±2.3	Investigate if skateboarding at community skateparks would elicit HRs and durations consistent with government recommendations for cardiovascular fitness in adults	Journal article (2020) CS, DESC Field		X		Adults participating in recreational skateboarding at community skateparks meet government exercise recommendations Average speed=6.5±1.9 km/hr Maximum speed=19.26±3.44 km/hr Average session duration=65.47±36.17 min Moving=62% (40 min) Stationary=38% (25 min) Average distance=4.58±4.5 km
Wood, Oliveira [22]	N=6 adult male skaters “with > ability to perform tricks”; experience (years): 9.0±4.2	Analyse and compare kinematics of ollie in static and dynamic (rolling) conditions	Journal article (2020) CS, CORR Lab	X		X	No significant kinematic differences between static and dynamic ollie (board COM height=0.24±0.0 m). Higher board height associated with higher front-foot knee flexion and ankle dorsiflexion

Klostermann and Küng [79]	N=9 adult male "skilled" skaters; experience (years): 14.3±3.6	Quantify eye gaze behaviour of experienced skateboarders and assess relationships with trick difficulty (tricks and obstacles)	Journal article (2017) CS, CORR Field			X	During approach, presence of obstacle caused skaters to shift gaze from board to TO area in front of obstacle during both kickflip and ollie. Skaters focused gaze on board when jumping and landing (kickflip and ollie)
Leuchanka, Ewen [25]	N=4 "experienced" adult male skaters; experience (years): 3.0±2.3	Quantify TO and LD forces during static ollie, and up and down platform	Pilot (2017) CS, DESC Lab	X			Pressure distribution during the take-off and landing centred on the medial forefoot Average peak TO forces: (ollie down) 2.34±0.32 BWs to (rolling ollie) 2.55±0.51 BWs Average peak LD forces: (static ollie) 2.40±0.33 BWs to (ollie down) 3.1±0.51 BWs
Pham [27]	N=11 adult skaters "with > 1 year of experience"; 9 males, 2 females	Investigate how biomechanics and energetics of skateboarding at various speeds compare to walking and running	Thesis (2016) CS, CORR Lab	X	X		Two distinct push-off styles: brakers and non-brakers Brakers applied more vertical force per stride (average peak vertical force (4 m/s): brakers=1.552±0.285 BWs non-brakers=0.723±0.490 BWs Energy costs when skating at 1.25 m/s like walking (average peak vertical force (1.25 m/s: brakers=0.91±0.21 BWs non-brakers=0.43±0.32 BWs) Energy costs at 3.0 m/s were half that of running at same speed (average peak vertical force (3.0 m/s): brakers=1.32±0.29 BWs non-brakers=0.59±0.43 BWs)
Vorlíček, Svoboda [16]	N=10 adult male skaters "with > 4 years of experience"	Compare muscle activity in ollie and switch ollie	Journal article (2015) CS, CORR Lab			X	Switch ollies required higher back limb muscle activity to maintain knee position. Skaters were unable to control an optimal force in the back leg during switch ollie (excessive or insufficient force). Skaters had better movement control and a greater ROM in front limb during ollie
Cesari, Camponogara [23]	N=20 adult males (N=8 adult male "expert" skaters "with > 3	Investigate how participants respond to a sound and simulate	Journal article (2014) CS, CORR	X		X	Skaters could anticipate and reproduce jump (shifting bodyweight 200 ms after sound).

	years of experience and training > 2x/week")	an ollie, and whether differences exist between skaters, youth, and adult non-skaters	Lab				Only skaters able to modulate forces under foot and muscle synergies resembling actual jumping
Candotti, Loss [80]	N=10 competitive male skaters "with > 2 years of experience" in amateur competitions	Identify relationships between ollie height and lower limb muscle force and power in beginner skaters	Journal article (2012) CS, CORR Lab		X	X	76.5% and 76.1% variance in maximum ollie skateboard explained by CMJ power and BM, respectively. 50.6% variance explained by dominant leg, knee extensor isometric strength and average ollie height was 64.5 cm.
Hetzler, Hunt [81]	N=10 adult skaters "with > 1 year of experience" and ability to skate for 1 hour without stopping to rest; 8 males, 2 females	Investigate if self-selected skateboarding pace elicits sufficient exercise responses to increase aerobic fitness and maintain healthy body composition	Research note (2011) CS, CORR Lab, Field		X		Estimated energy expenditure at self-selected skating pace for 30 mins (using HR)=10.3±3.1 kilocalories/min Total energy expenditure=308.6±37.9 kilocalories Estimated caloric expenditure for 30 mins of continuous skating on level surface consistent with government recommendations
Determan, Frederick [24]	N=12 adult "top professional or up-and-coming amateurs" skaters	Quantify ground reaction forces when sliding/grinding down 8-stair handrail and compare landing and bailing forces	Journal article (2010) CS, CORR Lab	X		X	Impact forces are significantly lower when landing compared to bailing (landing on feet) Maximum vertical forces: landing=7.98 BWs bailing=12.09 BWs Mean braking forces: bailing=2.4 to 5.4 BWs Average horizontal speed at TO: 4.5 m/s
Nevitt, Determan [26]	N=15 adult male "amateur" skaters	Quantify foot forces during push-off and define frictional requirements of skateboarding shoes	Technical note (2009) CS, CORR Lab	X		X	Three distinct push-off styles: heel-toe (resembling walking), mid-foot, and fore-foot (resembling sprinting). Differences in centre of force between grip tape vs. no grip tape Push-off forces: Grip tape=1054.9±286.6 N No grip tape=1038.4±273.5 N
Frederick, Determan [46]	N=7 adult competitive "top professional or up-and-coming amateurs" skaters	Quantify kinetics of ollie and movement patterns during LD	Journal article (2006) CS, CORR Lab	X		X	When skaters ollied off platform, they intentionally applied firm landing to stabilise position, creating higher than expected impact force, bore by forefoot and toes

				Peak LD forces=4.52±0.58 BWs at roughly 40-50 ms after contact Peak pop forces=2.25±0.13 BWs

BIPOC black, indigenous, and other people of colour; *HR* heart rate, *min* minute; *s* second; *bpm* beats per minute; *ROM* range of motion; *SJ* squat jump; *CMJ* countermovement jump; *DJ* drop jump; *BW* body weight; *BM* body mass; *m* metres; *m/s* metres per second; *km* kilometre; *km/hr* kilometres per hour; *min* minutes; *ms* millisecond; *N* Newton; *CS* cross-sectional; *CORR* correlational; *DESC* descriptive; *SIM* simulation; *TO* take-off; *LD* landing;

Data are displayed as mean±standard deviation, where relevant

[a] References appear in reverse chronological order
[b] No studies investigated tactical demands, so the column has been removed from the table

2.3.1.2 Publication Details

Articles obtained were published from 2006 to 2023. Most research was published after 2016 (n=11) [21, 22, 25, 72-79], including nine studies published between 2020 and 2023. Journal articles were predominant [16, 21-24, 46, 72-75, 78-80], with a single conference proceeding (n=1) [76], letter to the editor (n=1) [77], pilot study (n=1) [25], research note (n=1) [81], technical note (n=1) [26], and thesis (n=1) [27].

2.3.2 Study Design

2.3.2.1 Overview

The search returned only cross-sectional study designs, including descriptive (n=4), correlational study designs (n=14), and a simulation study (n=1) [21]. No longitudinal or training studies were identified.

2.3.2.2 Participant Characteristics

The average number of participants was 17±19 (n=19 studies), ranging from a single-subject design (n=2) [21, 76] to 71 participants (n=1) [74]. The average age of participants ranged from 10.4±2.7 years [74] to 33.3±1.8 years [77]. Participant age was not reported in three studies [25, 26, 46]. Youth participants were included in two studies [72, 74], but only one specifically investigated youth skateboarders (<18 years) [74]. Where included, the average body mass of adult participants was 65.5 kgs (n=15) and average height ranged from 1.7 to 1.8 meters [16, 21, 27, 72-78, 80, 81]. Approximately a third of the studies included female participants [27, 72, 74, 75, 78, 81], but only two studies had more than two female participants [72, 74] and only one analysed females separately or reported sex-related differences [72].

“Non-competitive” skateboarders [21, 73, 74, 78] and “competitive” skateboarders [46, 75, 80] were used as participants; however, it was not specified in 12 studies whether participants were competitors [16, 22-27, 72, 76, 77, 79, 81]. Preferred skateboarding discipline (street or park) was only reported in 3 studies (i.e., “street”) [76, 77, 80], with preferred competitive discipline only identified in one of the three studies using competing participants [80]. Ten studies adopted experience-based inclusion criteria [16, 22, 23, 27, 72, 74-76, 78, 80, 81].

2.3.2.3 Analysed Movements

All but four studies required participants to skateboard for the research [23, 73, 75, 77]; performing a variety of jumps [16, 22, 23, 25, 46, 76, 79, 80], flip tricks [76, 79], grinds [24], and basic locomotion [26, 27, 81]. Only one study investigated a non-flip trick, a grind (or slide) on a handrail [24] (Table 6). When specified, ollies and flip tricks were performed both statically [21, 22, 25] and rolling (while moving) [16, 22, 24, 25, 46, 79, 80]. Vorlíček, Svoboda [16] conducted the only study that investigated switch stance manoeuvres. Also, in one study, researchers attempted to use sound to simulate a rolling ollie while participants stood stationary on force plates [23]. Beyond tricks, locomotion-based movement (repeated kick-push), like regulating speed to set up a trick, was also specifically examined for shoe frictional and physiological demands [27, 81].

2.3.2.4 Skateboarding Equipment

In kinetic skateboarding studies, researchers controlled for skateboarding shoes [24-26, 46] and wheels [27]. In addition, Hetzler, Hunt [81] required participants to use the same complete skateboard (deck, wheels, and trucks) during locomotion. The remaining studies either did not control any aspect of the skateboard equipment [72, 74, 78, 79] or did not specify [16, 22, 80].

2.3.2.5 Obstacles

Platforms [25, 46], hurdles [16, 79, 80], and handrails [24] were used as obstacles to perform tricks up to [24, 46] off of [24, 25, 46], and/or over [16, 79, 80]. Obstacle heights ranged from a 2cm hurdle for a switch ollie [16] to a 90cm tall handrail [24]. The exact obstacles, heights, and tricks performed can be found in Table 7.

2.3.2.6 Laboratory or Field-Based Measurements

Most studies adopted solely laboratory-based measurements of skateboarding [16, 21-27, 46, 73, 75-77, 80]. Five studies utilised field-based measurements, in which conditions more closely resembled those typically seen during recreational or competitive skateboarding [72, 74, 78, 79, 81] (e.g., at a local skatepark or over concrete/flat ground). A variety of methods for measuring locomotion in skateboarding were researched; skateboarding on an instrumented treadmill [27], over a force plate [26], and around a concrete track [81].

2.3.3 Biomechanical Demands

2.3.3.1 Overview

Both kinetics [23-27, 46] and kinematics [21, 22] were quantified and were divided into characterisations of locomotion [26, 27] and tricks [21-25, 46].

2.3.3.2 Landing

Two journal articles and a pilot study specifically focused on the landing aspect of tricks [24, 25, 46]. Pressure sensing insoles [24, 25, 46] and force plates [24, 46] were used to quantity impact forces when landing from an ollie (36 cm, 45.7 cm) [25, 46] or 8-stair (2.13 m) handrail grind/slide [24].

2.3.4 Physiological Demands

2.3.4.1 Overview

Nine studies reported on the physiological demands of skateboarding [27, 72-75, 77, 78, 80, 81]. Both aerobic [27, 74, 78, 81] and anaerobic [73, 75, 77, 80] demands were quantified in laboratory [27, 73, 75, 77, 80] and field [72, 74, 78, 81] conditions. Three studies attempted to detect associations between physiological measures and presumed skateboarding performance metrics such as ollie jump height [80], subjective performance ranking [73], and career status/experience [75]. Only three studies included skateboarding tricks and obstacles when assessing physiological demands [72, 74, 78], and no research was found that specifically quantified the physiological demands of specific or consecutive skateboarding tricks.

2.3.4.2 Aerobic

Five research studies investigated the physiological aerobic demands of skateboarding [27, 72, 74, 78, 81] in adult [78] and youth [74] populations. Aerobic demands of tricks [25, 73, 75] and locomotion were assessed [27, 81].

2.3.4.3 Anaerobic

Skateboarders of various skill levels were tested for physiological strength [77, 80], power [73, 80], and flexibility [75]. Only the lower limbs were researched, specifically isometric hip extension [80], and isometric [80] and isokinetic knee flexion and extension [77]. Lower-limb power was assessed using unilateral [73] and bilateral jump tests [80]. Asymmetries in lower-limb strength and power were also analysed [73, 77]. No female strength and power data were measured. Only one study assessed the stability, balance, and range of motion of professional and amateur skateboarders [75].

2.3.5 Technical Demands

2.3.5.1 Overview

Ten studies investigated the technical demands of skateboarding skills [16, 21-24, 26, 46, 76, 79, 80]. None investigated consecutively performed skateboarding tricks, and as such, no evidence was found on "flow and consistency" or repetition. Furthermore, no studies were found investigating subjective measures of style. Thus, this scoping review only captures World Skate's objective "execution of style": speed, height, distance, and quality of landing of single trick attempts (Table 6).

No technical studies included female participants, and competitive skateboarders participated in only two technical studies [46, 80]. Also, only one technical study collected data outside the laboratory environment [79]. Kinetics [23, 24, 26, 46] and kinematics [21, 22] were quantified, and technologies used to understand the technical demands of tricks included electromyography (EMG) [16, 23], motion capture [21, 22] or video recording [16, 79], force plates [23, 24, 26, 46], a load cell [80], an eye-tracking system [79], and an inertial measurement sensor (IMU) [76].

Table 6: World Skate judging criteria and relevant studies including study methodology details like trick types, obstacles, objective measures, and any overall outcomes related to skateboarding performance

World Skate Judging Criteria[a]	References	Trick Types	Obstacles	Objective Measures	Relationship to Performance[b]
Difficulty and Variety of Tricks	[16, 22-24, 46, 76, 79, 80]	Ollie, switch ollie, kickflip, handrail grind, shove-it, nollie, FS 180	Handrail, platform, hurdle	Jump height Muscle activity (EMG)	Greater muscle activity required for switch ollie compared to ollie Altered gaze strategy with increased difficulty of tricks (ollie vs. kickflip)
Speed	[72, 74, 78, 81]	Locomotion only (or not specified tricks)	Not specified	Average, minimum, maximum speeds reached	Not specified
Height and Distance	[7, 19, 69, 71, 78, 82]	Ollie [21, 22, 25, 46, 79, 80], Kickflip [79]	Hurdle, platform	Submaximal (per obstacle height) and maximal board and athlete COM height	Not specified
Quality of Landing	46	Ollie	Platform	Foot pressure	Not specified

EMG electromyography; *FS* front-side; *COM* center of mass;

[a] The World Skate judging criteria most closely related to the article findings and associated objective measures.
[b] Skateboarding performance (e.g., greater muscle activity is required to perform more difficult tricks, or a higher jump height is related to a greater competitive score).

Table 7: A summary of included studies (ordered by publication year) relevant skateboarding-specific methodological and study design details

Reference	Study Design Details (skateboarding style, length of sessions, isolated tricks, etc.)	Environment (concrete, lab floor, skatepark, etc.)	Equipment (shoes, wheels, deck, trucks, etc.)[a]	Tricks (type, static or rolling)	Obstacles (type, height)	Performance Assessments	Constraints
Nessler, Lundquist [72]	1-hour skate sessions, presumably street-skateboarding	Local skatepark	Not controlled for or measured	Included, but not controlled for or measured	Included, but not controlled for or measured	None	None
Clark, Bishop [73]	General skateboarding[b]	Not provided	Not provided	Not provided	Not provided	Subjectively ranked on ability to land difficult tricks consistently	Not provided
Furr, Nessler [74]	1-hour skate sessions, presumably street-skateboarding	Local skatepark	Not controlled for or measured	Included, but not controlled for or measured	Included, but not controlled for or measured	None	None
Ou, Chen [75]	No skateboarding involved	–	–	–	–	–	–
Rasid, Kamarudin [76]	Isolated, street-skateboarding tricks	Laboratory floor	Not controlled for or measured	All tricks presumably static; ollie, kickflip, shuv-it, nollie, FS 180	None	None	Constrained by size of motion capture space (not provided)

Nakashima and Chida [21]	Isolated, street-skateboarding tricks	Laboratory floor	Not controlled for or measured	Static ollie	None	None	Tricks performed on force plate (size not provided)
Pietta-Dias, Ruas [77]	No skateboarding involved	–	–	–	–	–	–
Wiles, Kellogg [78]	1-hour skate sessions, presumably street-skateboarding	Local skatepark	Not controlled for or measured	Included, but not controlled for or measured	Included, but not controlled for or measured	None	None
Wood, Oliveira [22]	Isolated, street-skateboarding tricks	Laboratory floor	Not provided	Static ollie, rolling ollie	None	Board and skater COM height	Participants required to “pop” on designated mark, 3 m after start of 10 m walkway
Klostermann and Küng [79]	Isolated, street-skateboarding tricks	Outdoor carpark (flat, refurbished pavement)	Not controlled for or measured	Rolling ollie, rolling kickflip	20 cm hurdle (ollie) 12.5 cm hurdle (kickflip)	None	Started from standing at position marked by cross, then kick-push 12 m in straight line into jump zone (4 m long x 3 m wide)
Leuchanka, Ewen [25]	Isolated street-skateboarding tricks	Laboratory floor	Standardised shoes	Static ollie, rolling ollie, ollie down	36 cm tall platform (length unknown) (ollie)	None	Length of platform constraining TO of ollie down platform
Pham [27]	Flat-ground locomotion	Treadmill	Standardised wheels	Kick-push	None	None	Width and speed of treadmill
Vorlíček, Svoboda [16]	Isolated street-skateboarding tricks	Concrete	Not provided	Rolling ollie, rolling switch ollie	20 cm hurdle (ollie) 2 cm hurdle (switch ollie)	None	25 m of track

Cesari, Camponogara [23]	No skateboarding involved	–	–	–	–	–	–
Candotti, Loss [80]	Isolated, street-skateboarding tricks	Laboratory floor	Not provided	Rolling ollie	Hurdle (5cm increments)	Max hurdle height cleared	None
Hetzler, Hunt [81]	Flat-ground locomotion	Treadmill flat-ground concrete track	Standardised completes (deck, truck, wheels)	Kick-push	None	None	Width and speed of treadmill
Determan, Frederick [24]	Isolated, street-skateboarding tricks	Laboratory floor	Standardised shoes	Handrail slide or grind	8-stair handrail (2.13 m high) (62° from horizontal, 0.91 m above flat at start, 0.90 m from flat at bottom)	None	Landing constrained by force plate at bottom of hand rail (1.2 m long, 0.48 m from bottom of stairs) TO constrained by 8.2 m flat ground platform leading to handrail
Nevitt, Determan [26]	Flat-ground locomotion	Laboratory floor	Standardised shoes	Kick-push	None	None	Direction constrained by embedded force plate (size not provided)
Frederick, Determan [46]	Isolated, street-skateboarding tricks	Laboratory floor	Standardised shoes	Ollie-up, ollie-down	46.7 cm tall platform (length unknown)	None	LD and TO constrained by force plate placed 80 cm beyond platform end

COM center of mass; *FS* front-side; *m* meters; *cm* centimeter; *TO* take-off; *LD* landing;

'–'=Not applicable

[a] If not explicitly stated, equipment use was up to participant and not controlled for or measured
[b] Lead author ranked participants by 'skateboarding ability'; no details surrounding actual judged skateboarding were provided (when they skated, what tricks, how many, style, etc.)

2.3.5.2 Difficulty and Variety of Tricks

The successful execution of tricks was not related to competition. Most literature investigated the ollie manoeuvre [16, 22, 23, 46, 76, 79, 80], with one study simulating an ollie without a moving skateboard [23]. Researchers also investigated presumably more difficult tricks, such as the switch ollie [16], kickflip [76, 79], and grind [24].

2.3.5.3 Speed

No evidence of speed being measured (athlete (horizontal, vertical, or rotational speed) or board rotational speed (flip speed)) during specific skateboarding tricks to relate to performance metrics was found. Although Determan, Frederick [24] reported approach speed (4.5 m/s), no other horizontal or vertical speed of the skateboarder before or after landing was reported. The speed of locomotion was measured in four studies [72, 74, 78, 81]; however, only three measured speed in typical skateboarding environments (e.g. at a local skatepark with obstacles) [72, 74, 78]. No locomotion speed in a competitive setting or with competitive skateboarder participants was reported.

2.3.5.4 Height and Distance

Measures of height included maximum ollie board height determined by the maximum obstacle height cleared [80], obstacle-defined height [25, 46, 79], maximum athlete centre of mass height [22], and maximum board height [21, 22]. Trick heights were measured during static and rolling conditions, and measured using motion caption [22], force plates [21], and by obstacle height [16, 24, 25, 46, 79, 80]. Distance-related metrics such as rail length, grind time, or take-off and landing distance were unmeasured.

2.3.5.5 Quality of Landing

A single study [24] measured pressure under the soles and visually assessed landing strategies, however, the quality of landing was not related to either subjective or objective performance.

2.4 Discussion

2.4.1 Overview and Main Findings

A scoping search of peer-reviewed literature was conducted to; (1) identify the physical, technical, and tactical demands of competitive skateboarding, (2) synthesise the findings of the peer-reviewed literature, and (3) highlight limitations and gaps in the literature to guide future research directions. No research explored the tactical demands of competitive skateboarding. Surprisingly, although competitive athletes were used as participants, no research existed relating the demands of skateboarding to performance in a competitive environment. The literature is dominated by laboratory-based measurements of fundamental, isolated skateboarding tricks (e.g., kinetics and kinematics of the ollie). Moreover, the inconsistency and lack of skateboarding terminology further complicated the ability to synthesize findings for practical outcomes. Thus, all research included in the review and subsequent discussion on findings related to performance is presumptive about what constitutes and distinguishes competitive performance in skateboarding.

2.4.2 Study Design

Although various cross-sectional study designs were utilised to quantify the physical and technical demands of skateboarding, the lack of standardisation or consistency in terminology rendered comparing findings between groups (e.g., sex, age, skill level, discipline) and synthesising across studies difficult. The two Olympic skateboarding disciplines, park and street, vary in format and trick selection. Like other freestyle sports with multiple disciplines (freestyle vs. downhill snowboarding), the skills (presumably) required to perform them likely differ [60]. Of the few studies that defined participant skateboarding styles, associations with skateboarding performance were unexplored.

We suggest future research should specify the preferred skateboarding discipline of participants, to ensure sample group findings are applicable and representative of the wider population. Moreover, consistent terminology should be adopted when describing intra-participant characteristics, such as the preferred skateboarding stance (left vs. right foot, front vs. back foot, dominant vs. non-dominant). We recommend that authors clarify both the preferred skateboarding stance (goofy or regular) and dominant leg (leg which athletes would prefer to kick a ball) [73]. This should ensure all tricks and their associated difficulty, such as switch tricks, can be consistently and correctly compared.

Along similar lines, equipment use, standardisation and subsequent reporting were inconsistent. The degree to which this might influence observed results and interpretation is unknown, but ground reaction forces and joint kinematics in similar sports (e.g., freestyle snowboarding) are known to be sensitive to equipment design and choices (e.g., boot wear, binding angle) [83]. In skateboarding, studies measuring landing impacts would likely be affected by the wheels' hardness and the trucks' tightness, resulting in potentially a high amount of uncontrolled variance [24]. Nonetheless, addressing this in research could be complicated since skateboarding equipment and set-up (e.g., truck tightness) are highly individual to the skater's preference [53]. Requiring all participants to use the same equipment may not be feasible or ecologically valid. So, researchers should attempt to control equipment in other ways, such as intra-participant normalisation [47].

A lack of consensus on the performance calibre of skateboarders was also evident. Most researchers utilised unreliable time-based metrics to define participants' level of training and skill. Participant skill level was presented both objectively [16, 21-23, 27, 72-74, 76, 79, 80] as "years of experience", and subjectively [21, 23-26, 46, 72-81], referencing the level of experience ("recreational", "amateur", "professional", "skilled", "highly-skilled", "experienced", "expert", and "competitors"). Learning in action sports is very individualistic [51], with likely high movement skill transfer from one freestyle board sport to another [84]. Specifically, Künzell and Lukas [84] found skateboarding lessons to facilitate learning to snowboard, challenging the notion that more "years of experience" equates to a higher skill level. A standardised framework to identify the training and performance calibre of skateboarders is necessary for research to follow the basic principle of specificity [82]. A robust and objective definition of skateboarding cohorts would allow comparison between and within studies. We propose that future skateboarding researchers utilise an approach per recommendations provided by McKay, Stellingwerff [82].

Skateboarding performance is assessed using subjective scores allocated during judging. The scores are intended to differentiate the placing of skateboarders [13], rather than act as a highly sensitive instrument to reflect the specific magnitude of performance difference [82]. Thus, we recommend competitive skateboarding research should rely on proximal rankings from governing bodies (e.g., World Skate) to classify participant skill levels.

2.4.2.1 Ecological Validity of Tests Used

Ollie jump height was used most as the KPI by academics exploring physical and technical demands (Table 6 and Table 7). The reason for this selection is understandable, as anecdotally the more height a skater can achieve, the larger the potential obstacles they can utilise, or could allow more airtime to perform flips and rotations of the board. Both presumably would increase trick difficulty and associated score, although importantly, this remains unexplored. Nevertheless, how ollie jump height was measured varied greatly (static vs. rolling). Notably, the difference in testing severely limits the ability to compare findings across studies.

Studies that utilised force plates during the ollie either constrained take-off or landing point [21, 22, 24, 46, 79]. While understandable due to laboratory limitations and standardisation practices, imposing these constraints on the skaters may have altered technique and result in sub-maximal heights. Along similar lines, neither take-off nor landing speed were reported during ollie jump tests. The speed before take-off likely greatly affects technique and ability to gain maximal height [85]. Thus, by limiting the distance to take-off, these tests potentially measured the optimal technique for that specific scenario only, instead of maximal capability. Although authors reported both maximum board [22, 25, 26, 46, 79, 80] and athlete jump height [22] during the ollie, most jump heights reported were actually the minimum height as determined by the obstacle used [25, 46, 79, 80]. Candotti, Loss [80] measured maximal ollie jump height by raising a hurdle height with each successful attempt at clearing the obstacle. Although arguably a more ecologically valid approach, the sensitivity was limited to 5-cm increments. Future research should specify the construct and metrics assessed (maximal vs. submaximal rolling or static height) and design the test accordingly. This is a defined criteria in street and part skateboarding used by judges to distinguish performances [13], so researchers should utilise established reliable technology, such as video or in-shoe sensors [22], to measure board height.

2.4.3 Demands

2.4.3.1 Physiological

The physiological demands of park skateboarding were not specifically addressed in the literature. In street skateboarding, Furr, Nessler [74] and Wiles, Kellogg [78] found that skating for an hour at the skatepark mimicked heart rates and intensity intervals of gym-based high-intensity intermittent training. While unclear, this seemingly included all flip tricks, rest periods, changes in elevation, and the use (or not) of obstacles. Average adult speeds while moving in the skatepark (6.5±1.9 km/hr) [78] were comparable to those controlled by Pham

[27] (4.5 and 10.8 km/hr) when investigating the energy requirements of the kick-push. Locomotion speeds used by Hetzler, Hunt [81] (17.05 km/hr) were more comparable with top speeds reached by both youth (17.19±3.92 km/hr) [74] and adult (19.26±3.44 km/hr) [78] skaters.

No studies accounted for skateboarding session variation (tricks attempted, tricks landed/bailed, utilisation and height of obstacles, types of tricks, etc.). Since bailing a trick resulted in significantly greater impact forces than landing [24], the physiological demands on each skater would likely depend on session characteristics. For example, we speculate that an hour of attempting a jump from an 8-stair handrail would almost certainly require greater mechanical demands than an hour session at the skatepark with occasional submaximal ollies on flat ground. We suggest future researchers should aim to quantify the trick details of skateboarding sessions to understand the physiological demands of various skateboarding styles and disciplines (street and park). This could have spanning implications for coaching, specifically for load management strategies related to injury risk [86].

The high-intensity, intermittent nature of recreational street skateboarding [74, 78] shows some similarities to competitive surfing [36]. Though, surfers must recover quickly during short rest periods (20-second paddling periods, followed by stationary 10-second periods), which does not appear to be the case in skateboarding, with much longer rest periods between runs and best-trick attempts [53]. Adult recreational skateboarders spent 18% of their session stationary for over 1 minute [78]. Although this may not reflect competitive skateboarding sessions or competitions, it would seem from the current evidence that skateboarding is less aerobically demanding than surfing, with skateboarding activity typically lasting less than 45 seconds, in both park and street competition run formats [13]. Also, rest periods between competitive runs typically range from 3 to 8 minutes [53]. Thus, skateboarding physiological demands may more closely resemble freestyle snowboarding, where aerobic fitness does not appear to significantly determine performance, and the rest periods between runs are similar. Regardless, where aerobic fitness may be advantageous for training and recovery, anaerobic fitness probably has greater direct performance-related benefits for skateboarders [87].

Skateboarding research that investigated the anaerobic demands focused solely on the lower body. When compared to "performance", Candotti, Loss [80] found that power in the countermovement jump (CMJ) could explain 76.3% of ollie jump height. Also, 50.6% of ollie height could be explained by knee extensor muscle strength of the dominant limb (typically the back foot) [16]. Amateur competitive skateboarders achieved jump heights of 35.3±4 centimetres and 44.4±6.3 cm in the squat jump (SJ) and CMJ, respectively. Similar CMJ heights were achieved by elite freestyle snowboarders (32.5 to 48.9 cm) and Olympic male volleyball players (44.5 cm) [88]. Interestingly, CMJ height was considered a significant determining factor between selected (49±5 cm) and non-selected (42±7 cm) elite male competitive surfers [45]. Lower body dynamic strength production is likely also important to skateboarding, particularly during the "pop" preceding most street tricks [21]. Unfortunately, no studies in skateboarding compared anaerobic capabilities and associated outcomes, such as CMJ height (or even ollie jump height), to competitive performance success (e.g., scores within a run or competition standings). Thus, the relationship of these factors to better performance is speculative.

Due to the asymmetrical nature of skateboarding, some hypothesised that unilateral anaerobic capacities could be important [73]. However, no significant between-limb differences have been observed [73, 77] nor were between-limb asymmetries in jump power clearly detrimental to the performance (jump height) of experienced, recreational skateboarders [73]. So, although the evidence is weak, there appears to be an importance of bilateral lower body strength and power underlying skateboarding performance [21, 80]. Yet counterintuitively, performance may be less sensitive to strength and power asymmetries [73, 77], potentially due to skateboarders performing tricks in different, more demanding stances (switch, fakie).

Increased ankle dorsiflexion range of motion allows athletes to handle the forces during aerial landings [89], and greater dorsiflexion in the front ankle appears associated with a higher ollie jump height [22]. Similarly, in surfing, greater ankle dorsiflexion range of motion was a distinguishing performance factor [89]. Professional skateboarders reported similar ankle dorsiflexion range of motion values (front foot=43.50±7.47°; back foot=42.00±7.75°) to competitive surfers (front foot=43.0°±8.2°; back foot=42.6°±7.2°) [75]. Therefore, while speculative, greater ankle dorsiflexion range of motion, especially in the front foot, could be related to improved performance and reduced injury risk.

2.4.3.2 Biomechanical

Research primarily focused on the kinematics and kinetics of aerial tricks and associated landings. Vertical landing ground reaction forces ranged from 4.52±0.58 [46] to 7.98 BWs [24] in the static ollie and handrail grind/slide, respectively. Comparatively, surfers typically experience up to six BWs of force during aerial landings [17], and big air slopestyle skiers experience about two BWs of force during landings [90]. Determan, Frederick [24] also measured vertical forces up to 12 BWs when the skater deliberately bailed and landed on their feet rather than on top of their board. Higher impact forces are thought to contribute to injuries in gymnastics, where athletes hit up to 14 BWs of force, when like skateboarders, they deliberately "stick" the landing [91]. Thus, skateboarders may benefit by adopting strategies to cope with the repetitive high forces experienced during trick landings to improve the quality and minimise the risk of injury.

Although the biomechanical skateboarding studies included in this scoping review measured similar trick landing forces, there were conflicting results on force application points from the pressure insole sensors used [24, 25, 46]. Also, there was no clear agreement regarding the location of force application during skateboarding locomotion [26, 27]. So, although forces experienced by skateboarders can be high (relative to other similar sports), both take-off and landing styles and techniques likely impact the force applied and attenuated. While training methods have been implemented in various skill-based board sports to enhance landing technique [92], the impact of such training on skateboarding style (specifically, landing quality) and subsequent competitive performance remains unknown. For instance, as previously mentioned, skaters frequently achieve a clean landing by deliberately exerting additional pressure on the board upon touchdown [24]. Although this elevates the forces involved [24], potentially increasing the injury risk [93], it could enhance trick execution or even positively influence the judges' perception of style and landing quality [94, 95]. The association between take-off and landing techniques and forces during tricks, and more broadly performance, should be investigated.

2.4.3.3 Technical

Klostermann and Küng [79] found a strong link between specific task demands and visual information processing. Including an obstacle altered the fixed visual attention (gaze) strategy of "skilled" (14.3±3.6 years of experience) male skateboarders. When attempting to ollie over a 20 cm hurdle (12.5 cm hurdle for a kickflip) compared to a rolling ollie with no obstacle, skateboarders shifted their gaze during the approach from looking at the skateboard (34.4% (no obstacle) vs. 16.8% (obstacle) of approach time), to focus on the area in front of the obstacle. In addition, when required to perform more technical tricks without an obstacle (e.g., kickflip), skateboarders focused on their skateboard longer than when performing an ollie. After the take-off, neither the trick difficulty (kickflip vs. ollie) nor the obstacle appeared to affect gaze behaviour; all skateboarders directed their gaze to the board for landing [79]. Thus, gaze strategy adjustment due to obstacles may indicate a change in trick difficulty, a key judging criterion [13]. The only obstacles utilised in the research were platforms [24], hurdles [16, 79, 80], and a handrail [24], but no studies included tricks performed on ramps, quarter pipes, or inclined surfaces. Hence, future research should include and define more obstacles when assessing skateboarding performance and related underlying demands, despite there being no understanding of the relationship between obstacle choice and competitive success.

In addition to the gazing strategy being an indicator of difficulty, the shifting of body weight and musculature activity may also indicate increased trick difficulty [23] and differentiate performance. Attempting tricks in switch stance required increased muscular strength and coordination of the lower limbs [16], suggesting that skaters must produce force quickly by shifting their body weight and maintaining balance by evenly distributing force across the lower limb muscles. It would seem skaters utilise lower-limb muscle coordination to cope with high landing forces while maintaining stylish elements.

In addition to a capacity to cope with high forces, lower limb flexibility also appears to be an important skill when attempting and landing tricks at height. In addition to flexing their ankles, knees, and hips to dampen the load and find balance on the board [46], skaters flexed their lower limbs in the air to obtain a higher board height, important when trying to clear obstacles [22]. This was echoed by Nakashima and Chida [21], who suggested the importance for the skateboarder to pull up the front foot "early and rapidly" during the take-off stage of the ollie. Moreover, the amount of force (strength) applied to the board during the pop was less important to maximum jump height than the speed at which that force is applied [46], suggesting the relationship between strength and speed influences technique. Therefore, as anticipated, skateboarding appears a technical sport, requiring athletes to produce force effectively and efficiently and have enough lower limb range of motion to obtain maximum height and dampen landing forces.

2.4.3.4 Tactical

The subjectivity of skateboarding renders it complicated to objectively determine what distinguishes and constitutes success. Compared to traditional sports with objective winning differentiators (e.g., athletics), skateboarders are ranked each round; how judges determine these rankings, and whether they are consistent within and across competitions, is unknown. Yet, no published research to date explores the tactical demands of competitive skateboarding, and thus coaches are left to speculate how to support skaters to be successful at competitions. Furthermore, while an attempt has been made to explore and interpret findings on various demands, their practical utility remains unclear without knowing how these relate to competition performance. This sets a clear prioritisation for future research direction to explore the tactical demands of competition and then the underlying capacities required.

2.4.4 Summary and Recommendations for Future Research

Skateboarding is an individual, skill-based sport, and performance presumably relies on essential physiological, biomechanical, technical, and tactical skills to achieve success [17, 59]. Although previous research, as reported in the scoping review, attempted to understand various skateboarding demands, there is a general lack of standardisation and thorough reporting across studies, restricting synthesis. More importantly, it is imperative to acknowledge that the term "performance" is frequently used despite lacking empirical evidence establishing the criteria for a truly successful skateboarding performance (or competition). Thus, findings from this review and associated literature are speculative. To address this critical gap, future research must first look to objectively identify the tactical demands of competitive skateboarding, before attempting to assess methods of differentiating and improving performance.

Future research must consider the ecological validity of study methodologies when concluding findings. Study design should be standardised and reported, including equipment (e.g., standardisation of shoes), metrics selected (e.g., board height vs. athlete height), technology (video analysis), analytical approaches (e.g., determination of jump height calculations), and terminology. Skateboarding, like traditional sports, is inextricably linked to the environment [51], evidenced by the communities' high values of creativity and free-nature culture [8]. For example, it is rare for athletes to compete solely on flat ground; all Olympic-qualifying street skateboarding competitions are performed in a "skatepark" with various obstacles, inclinations, and surface types [53]. Thus, research should not remove aspects of the environment and competition constraints that are critical to understanding performance. This may be a challenging undertaking, given the trade-off between ecological validity and standardisation (accuracy); a certain degree of control is required to reduce variance to draw conclusive findings from the study [51]. As such, careful consideration should be taken when designing a study to ensure accuracy, without sacrificing the applicability to the real world, a challenge for all applied sport science research. Also like many traditional sports, the skateboarding literature suffers from an underrepresentation of females [8]. Future skateboarding research should explore both male and female skaters to effectively improve performance and reduce injury.

2.5 Conclusion

This scoping review identified large gaps in the skateboarding literature, with few studies using competitive skateboarders, and inconsistent terminology complicated the ability to delineate discipline-specific outcomes. There is some data suggesting certain aspects of the sport require quick and high force output of the lower limbs and draws on anaerobic energy sources. Most research focused on quantifying isolated tricks, with lower-limb power potentially valuable when attempting to maximise ollie height, and indications that flexibility might be a factor. Nonetheless, effectively no research investigated tactical demands, which renders the practical utility of the current research questionable, since it is presently unclear what constitutes and underlies an objectively better performance in street and park skateboarding. Thus, skateboarding appears a technical sport requiring athletes to produce force effectively and efficiently, utilising lower-limb muscle coordination to cope with high landing forces while maintaining stylish elements.

CHAPTER 3:

EXPLORING PERCEPTIONS OF SUCCESS IN OLYMPIC COMPETITIVE AND AMATEUR STREET AND PARK SKATEBOARDING AND IMPLICATIONS FOR TRAINING

This chapter comprises the following paper published in the *International Journal of Sports Science and Coaching*:

Diewald, S. N., Thorpe, R.T., Martinez, A., Neville, J., Cronin, J. B., & Cross, M. R. (2025). Exploring Perceptions of Success in Olympic Competitive and Amateur Street and Park Skateboarding and Implications for Training. *International Journal of Sports Science and Coaching*. https://doi.org/10.1177/17479541251333892 [Epub ahead of print]

Prelude:

In the previous chapter, a review of the literature revealed few studies had explored the physical and technical demands of skateboarding. The available evidence suggested that skateboarding is a technical sport, with certain elements requiring flexibility and quick, high force output of the lower limbs. However notably, very few studies involved competitive skaters, and the tactical demands of competitive skateboarding were largely unresearched. Since the goal of this thesis is to provide insights for competitive skaters aiming to compete on the world stage, it is essential to understand what constitutes and underscores 'performance'. Moreover, the criteria by which skaters are ranked were developed to encompass the community's values. Thus, a critical step towards understanding performance is capturing the perspective of the skaters themselves, to ensure relevant and practical findings. Subsequently, the aim of Chapter 3 was to explore community views on skateboarding performance, relative to the subjective ranking criteria developed purportedly to reflect these values. Skaters of varying skill levels, community involvement, and disciplines were surveyed to determine how these factors related to perceptions of success. Specific attention was given to Olympic skaters, whose views on their performance evaluation, judging criteria, and training priorities offered crucial insights. For athletes to train effectively, specific knowledge of what it takes to be successful in the judges' eyes is required, making these skaters' unique experiences especially valuable.

CHAPTER 3: EXPLORING PERCEPTIONS OF SUCCESS IN OLYMPIC COMPETITIVE AND AMATEUR STREET AND PARK SKATEBOARDING AND IMPLICATIONS FOR TRAINING

3.1 Introduction

Competitive street and park skateboarding were introduced as Olympic sports at the Tokyo 2020 Games, continued in the Paris 2024 Games and have been approved for the Los Angeles 2028 Games [96]. Competition success is the result of combining subjectively determined scores by judges, who form a single score based on the 'overall impression' of a skater's performance [11, 97]. Although defined and publicly available, the criteria for ranking performance can be perceived as relatively vague and ambiguous. Moreover, due to the recency of Olympic inclusion, the format of the competitions continues to evolve, for example, the scoring format of street skateboarding in Paris 2024 ("2/5/3" on a 100-point scale) [97] was changed following feedback on the Tokyo 2020 format ("2/5/4" on a 10-point scale) [11]. Understanding what constitutes a better overall performance is of interest to those wanting to train and compete.

Despite format changes, the judging criteria for skateboarding has remained consistent throughout its Olympic presence. In competition, judges award points based on criteria developed by the skateboarding governing body, World Skate. The World Skate judging criteria (Figure 3) was created 'to foster and preserve the progression of skateboarding while highlighting the importance of creativity and originality" in a competitive environment. This includes (1) difficulty and variety of tricks, (2) execution, (3) use of course and featured obstacles, (4) flow and consistency, and (5) repetition; developed specifically to encompass the "values, principles, and virtues generally shared and accepted by skateboard communities" [97]. Although some of these criteria likely have an objective basis through which performance might be quantified, targeted, and improved, judging ultimately occurs through subjective lenses.

Moreover, no research exists to explain the tactical demands of the competitive environment [98]. Therefore, what ultimately constitutes judges' impressions and distinguishes competitive performance in elite street and park skateboarding is unexplored. For amateur skaters looking to progress in the sport to compete at the highest level, they need to focus their training effectively, which requires an accurate understanding of what it takes to be successful in the eyes of the judges [51].

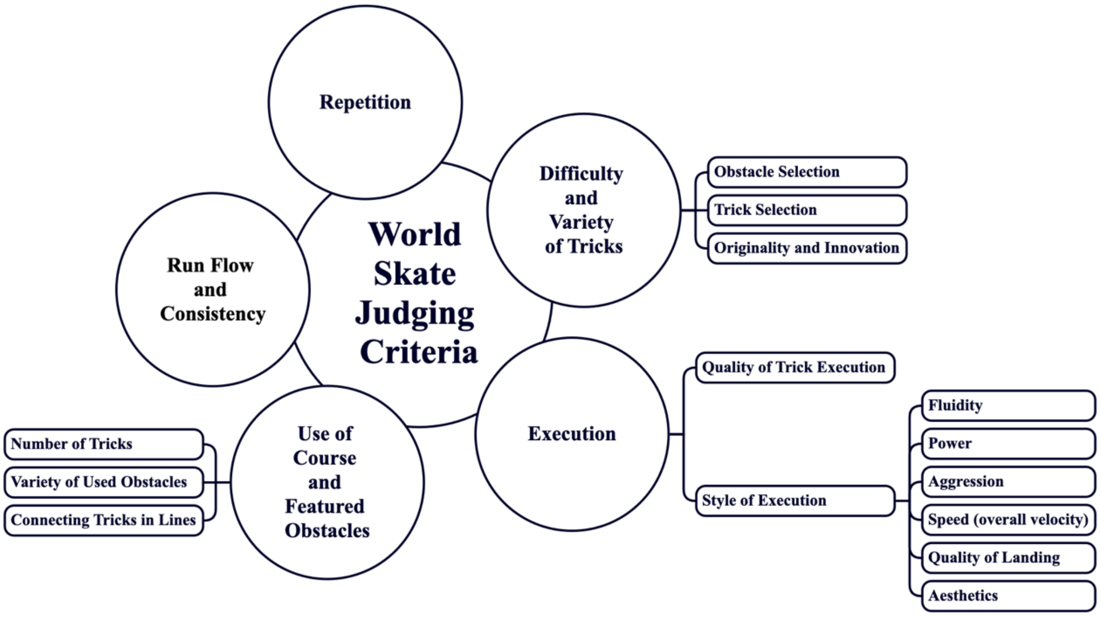


Figure 3: Visual representation of the World Skate judging criteria for street and park skateboarding; adapted from the World Skate Judging Criteria Bulletin 2022 [97].

Although the judging criteria were developed to reflect the community values, ironically, the incorporation of skateboarding in the Olympics contrasts with the sport's traditionally anti-mainstream ethos [99]. As such, skateboarders have expressed concern that decision-makers may lack core values of the community [100]. Moreover, the specific community of World Skate 'elite competitive' skaters has only come into existence since Olympic inclusion [15], warranting further exploration into how this community's values align with World Skate judging criteria and the wider recreational community. Along similar lines, street and park disciplines are currently judged using the same criteria; yet competition formats are different [97], with few skaters competing in both (https://www.worldskate.org/skateboarding/ranking-paris-2024.html, accessed: 3 July 2024). Understanding current perspectives on performance in skateboarding, and how they differ across athlete skill levels, is a crucial first step in determining whether the broader elite and amateur skateboarding communities fully comprehend the criteria that define their success and align their development priorities accordingly. Moreover, due to the notable differences in competition formats and skateboarding styles, whether these perspectives vary between disciplines is of additional interest.

Therefore, this study explores the understanding of skateboarding performance within the athlete community, focusing on how skaters perceive the criteria used to evaluate their performance and whether their training aligns accordingly. Through an online survey, this research aims to describe skaters' perceptions of what constitutes a good performance in competitive and recreational skateboarding and synthesise these insights with the current performance criteria established by World Skate. Furthermore, it compares the opinions of street and park skaters and examines whether perspectives differ by skill level (professional international elite vs. regional amateur) or form of involvement (competitive vs. recreational).

3.2 Methods

3.2.1 Experimental Approach to the Problem

In this cross-sectional study, competitive domestic and international skateboarders were invited to complete an online anonymous survey to capture their perspective on what constitutes a 'good' competitive skateboarding performance. Skaters recruited through social media and word-of-mouth were directed to a Google form (survey) which was open from 10 May 2023 until 1 January 2024. A mixture of random and convenience (pre-existing network) sampling was utilised to boost participant recruitment. From the data collected, mixed statistical methods were used to describe and compare perceptions between disciplines (street vs. park), forms of involvement (competition vs. recreational), and competitive skill level (elite vs. amateur competitors).

3.2.2 Participants

Subjects of all age, sex, and nationality could access and complete the online survey. New Zealand based skateboarders were recruited through social media with an advert including a link to the Google Form. Additionally, elite sponsored international skateboarders were deliberately recruited via word of mouth to ensure representation across varying levels of involvement within the sport, despite the expectation of limited sample sizes. In this fashion, we aimed to attain representative samples from each level of involvement within the sport – albeit expecting somewhat low sample sizes. Due to the primarily descriptive nature of the study and the anticipated challenges in achieving a larger sample size, no formal power analysis was conducted prior to data collection. The original design focused on descriptive outcomes, with any subsequent comparative analyses being exploratory in nature. Thus, the sample size was determined by practical considerations, including participant accessibility and the novelty of the research context.

Recruitment adverts were posted to online platforms. Additionally, the survey was shared via email to pre-existing networks to ensure participants were from the elite community. Information sheets describing the objectives and purpose of the study were included as the first page of the online survey. Participants were advised that progressing past the information page and submitting a response constituted consent to participate, and they were able to exit the survey without submitting at any time. Institutional ethics approval was granted by the Auckland University of Technology Ethics Committee (AUTEC #22/248).

3.2.3 Procedures

Participants were asked to answer 35 questions, across 6 sections (Appendix IV). Section 1 contained demographic (age, sex, nationality, residence) and skateboarding background questions (preferred stance, years of experience, preferred discipline, time spent currently skateboarding, current competing status). In addition, they were asked what success in skateboarding looked like to them from a predetermined list (winning competitions, representing their country, peer approval, etc.), selecting all that applied. Section 2 questions pertained to competitive experience (highest and current World Skate rank, first competition, number of competitions in the last year, highest level of competition) and coaching. In Section 3, skaters were asked to rank a list of World Skate judging criteria (Table 8 and Figure 3) by importance to competitive skateboarding performance and to select the most important factor to being the best competitive skater (in their opinion). Responses were recorded on a 5-point Likert scale (1-Not at all Important, 2-Low Importance, 3-Neutral, 4-Important, 5-Very Important) [101]. Next, participants were asked whether they felt their answers differed for recreational skateboarding (e.g., skating for fun). If participants indicated 'yes', they ranked the factors again based on recreational skating (Section 4). Notably, all participants answered questions regarding both competitive and recreational skateboarding, regardless of involvement level. In Section 5 participants selected which judging criteria they focused on when training to improve their skating performance (fun/competition, ticking all that applied). Lastly, in Section 6 participants responded if they used any technology or data to inform and guide their training and/or performance. Although participants completed all sections, Section 6 was not analysed or reported on in this study. No free-text responses were included in the analysis.

Table 8: Ranking of factor importance for competitive and recreational skateboarding.

Performance Factors[a]	World Skate Judging Criteria[b]: Repetition	Trick Difficulty and Variety	Execution	Course and Obstacle Use	Flow and Consistency
Trick Difficulty		X			
Trick Variety	X	X			
Obstacle Difficulty		X		X	
Obstacle Variety	X			X	
Trick Originality	X	X			
Quality of Trick Start (“pop”)			X		
Quality of Trick Landing (“bolts”)			X		
Style			X		
Trick Fluidity			X		
Power			X		
Aggression			X		
Aesthetics			X		
Speed		X	X		
Height		X	X		
Distance (grind time, air time, etc.)		X	X		
Number of Tricks Performed (e.g. during a run)				X	X
Number of Obstacles Used (e.g. during a run)				X	X
Linking Tricks (e.g. during a run)				X	X
Flow					X

[a] Factors were derived to encompass a range of World Skate judging criteria.
[b] See World Skate judging criteria (Figure 3)

Performance factors included in the survey encompass various World Skate judging criteria [11, 13], indicated by ‘X’.

3.2.4 Data Processing

All responses were downloaded in csv format to be used for statistical analysis, conducted in R Statistical Software (RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/, R base version 4.1.2). *Tidyverse* (version 1.3.2) [102] was used to clean and visualise the data, and the *likert* package (version 1.3.5) [103] was used to analyse and visualise responses to Likert questions (Section 3 and 4). Visualisation of Likert questions (Figure 4, Figure 5, and Figure 7) display percentages from left to right representing the percentage of participants that reported Not all important or low importance (1 of 2), neutral (3), and important or very important (4 or 5), respectively. The horizontal axes (0%, 50%, 100%) represent the percentage of values to the left and right of the centre line (0%), respectively, whilst splitting the neutral responses in half; left: neutral (3, half), low importance (2), or not at all important (1), and right: neutral (3, half), important (4), or very important (5).

3.2.5 Statistical Analyses

To describe perspectives of the skateboarding community on competitive and recreational performance factors, a mixed-methods approach was utilised, which involved a variety of descriptive frequency and qualitative analysis of responses. Where appropriate, additional comparative analyses were used. Specifically, we performed nonparametric tests to compare the opinions of competitive street (COMP-STREET) and park (COMP-PARK) skaters and examine if their skill levels (professional international elite, ELITE-COMP vs. regional amateur, AMT-COMP) and forms of involvement (competitive vs. recreational, AMT-REC) related to their responses. Fisher's exact test was used to determine if there were statistically significant differences in responses to dichotomous dependent variables ('Do your answers to competitive skateboarding differ from recreational, yes or no?') across skill-level (ELITE-COMP, AMT-COMP, AMT-REC (adjusted p-value)) and discipline groups (COMP-STREET, COMP-PARK). Fisher's exact test was chosen due to the presence of expected cell counts less than five in the contingency tables, providing a more accurate assessment for small sample sizes and violating the assumptions of other common tests. Mann-Whitney tests (via the W statistic) were used to determine if there were differences in responses between groups for ordinal dependent variable types (level of importance of factors) and interpreted via the effect size (r): $0.10 \leq r < 0.30$ – small effect, $r = 0.30 \leq r < 0.50$ – medium effect, and $r \geq 0.50$ – large effect. Alpha level was set at a=0.05.

3.3 Results

3.3.1 Participants

Forty-five skaters submitted responses. Responses from participants who were either not actively skating at least once per month (n=8), not a street or park skater (n=3 downhill or longboard), or completed less than 90% of the survey (n=1) were excluded. Once exclusion criteria were applied, 33 responses remained for analysis.

Of the 33 participants included in the analysis, 14 were competitive (Table 9). ELITE-COMP skaters were from four different countries; three of which competed at the Tokyo 2020 Olympic Games, and all four competed in World Skate qualifying competitions for the Paris 2024 Olympic Games. All 29 AMT skaters were from or residing in New Zealand at the time they completed the survey. Competitive skaters reported skating at least a few times per week, with 3/4 ELITE-COMP and 4/10 AMT-COMP skating every day for >30 minutes. All ELITE-COMP participants previously competed in over 20 competitions and had competed for at least 13 or more years. Seven AMT-COMP skaters (70%) previously competed in 10 or fewer competitions; of which six had their first competition after the Tokyo Olympics [within three years prior to completing the survey (2020-2022)].

Table 9: Demographic summary of survey participants

Group[a]	Number of Participants	Age (years)	Skating Background (years)	Current World Ranking[b]	Highest Achieved World Ranking[c]
ELITE-COMP	4 (4M, 0F)	25.5±2.89	11.5±13.61	24.3±23.64	15.0±15.98
AMT-COMP	10 (7M, 3F)	25.8±12.21	20±1.63	–	–
AMT-REC	19 (18M, 1F)	36.8±10.14	19.3±12.98	–	–
COMP-S	6 (2 ELITE) (5M, 1F)	23.8±6.31	11.3±8.57	10.2±23.46	6.7±15.37
COMP-P	8 (2 ELITE) (6M, 2F)	27.1±12.71	15.8±14.38	4.5±8.40	2.5±4.90

M male; *F* female; *COMP* elite competitive; *AMT* amateur; *REC* recreational; *S* street; *P* park;

[a] Community groups: ELITE-COMP (professional, internationally competitive elite); AMT-COMP (regionally competitive amateur); AMT-REC (regional recreational amateurs),; COMP-S (both elite and amateur competitive street); COMP-P (both elite and amateur competitive park)
[b] Self-reported current (day of submission) World Skate World Ranking
[c] Self-reported highest achieved (at any point) World Skate World Ranking

All values are presented as mean±standard deviation, unless otherwise noted

3.3.2 Competitive Skateboarding Performance

Overall, COMP and REC participants concurred World Skate criteria were important or very important to competitive skateboarding performance (Figure 4). More than 90% of participants reported trick variety, linking tricks, and flow as important or very important to competitive success. The lowest importance was placed on aggression, with 46% neutral regarding competitive success.

Of the entire sampled population, the most frequently selected criteria considered as 'most important' to competitive skateboarding performance were style (n=9, 0% ELITE-COMP, 20% AMT-COMP, 36.8% AMT-REC) and flow (n=7, 25% ELITE-COMP, 40% AMT-COMP, 10.5% AMT-REC). COMP skaters selected five different factors (out of 19) that were most important for competition success; flow with the greatest number of responses (n=5, 35.7% of COMP). REC participants selected nine different factors: the most for style (n=7, 36.8% of REC). Each ELITE-COMP skater selected a different factor (trick difficulty, flow, linking tricks, and trick variety). AMT-COMP skaters selected flow (n=4), trick difficulty (n=2), style (n=2), linking tricks (n=1), and trick variety (n=1) as the most important. COMP-PARK skaters felt flow was the most important (n=4, 50% of COMP-PARK), compared to one of six (16.6%) COMP-STREET skaters.

There was a statistically significant difference, with a small effect, between REC and COMP groups in the level of importance of obstacle variety (W=55.5, p=0.01, r=0.209), trick originality (W=64.5, p=0.02, r=0.242), fluidity (W=74, p=0.03, r=0.278), and linking tricks (W=66.5, p=0.04, r=0.25) (Figure 4). Obstacle variety was important or very important to 50% of ELITE-COMP participants, compared to 70% of AMT-COMP, and 94% of the AMT-REC, respectively. Originality was important or very important to 100% of ELITE-COMP, compared to 67% of AMT-COMP participants. AMT-COMP and AMT-REC skaters significantly differed on the importance of obstacle variety (W=44.5, p=0.03, r=0.234) and trick originality (W=38, p=0.02, r=0.2).

There was a statistically significant difference between COMP-STREET and COMP-PARK groups in the importance level of aesthetics (W=3, p=0.01, r=0.062) and trick originality (W=8, p=0.04, r=0.167) to overall competitive performance (Figure 5); COMP-STREET placing more importance on both. Although not statistically significant, COMP-PARK participants reported higher importance on trick and obstacle difficulty, height, and power, but lower importance on obstacle variety and trick originality compared to COMP-STREET.

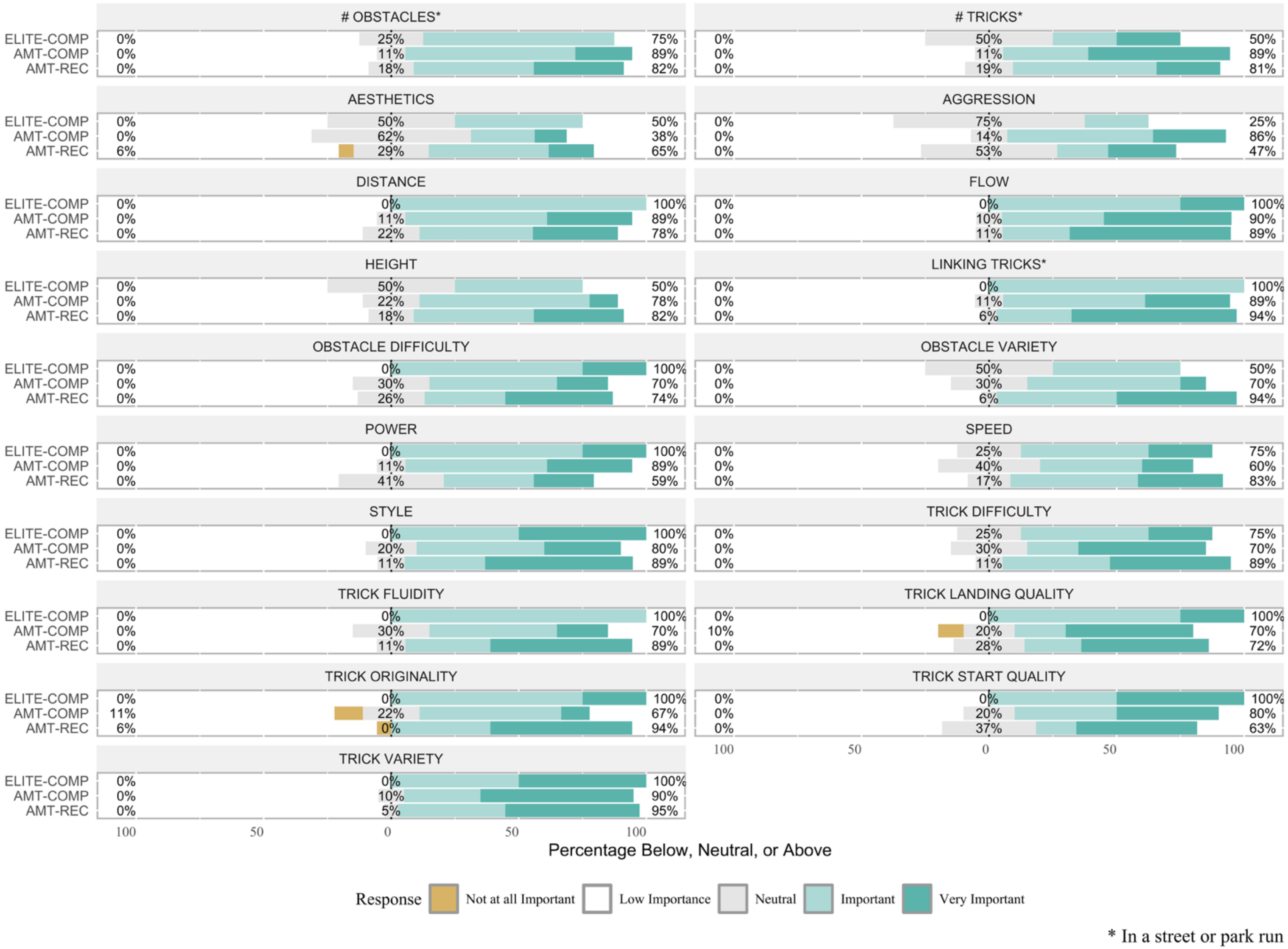
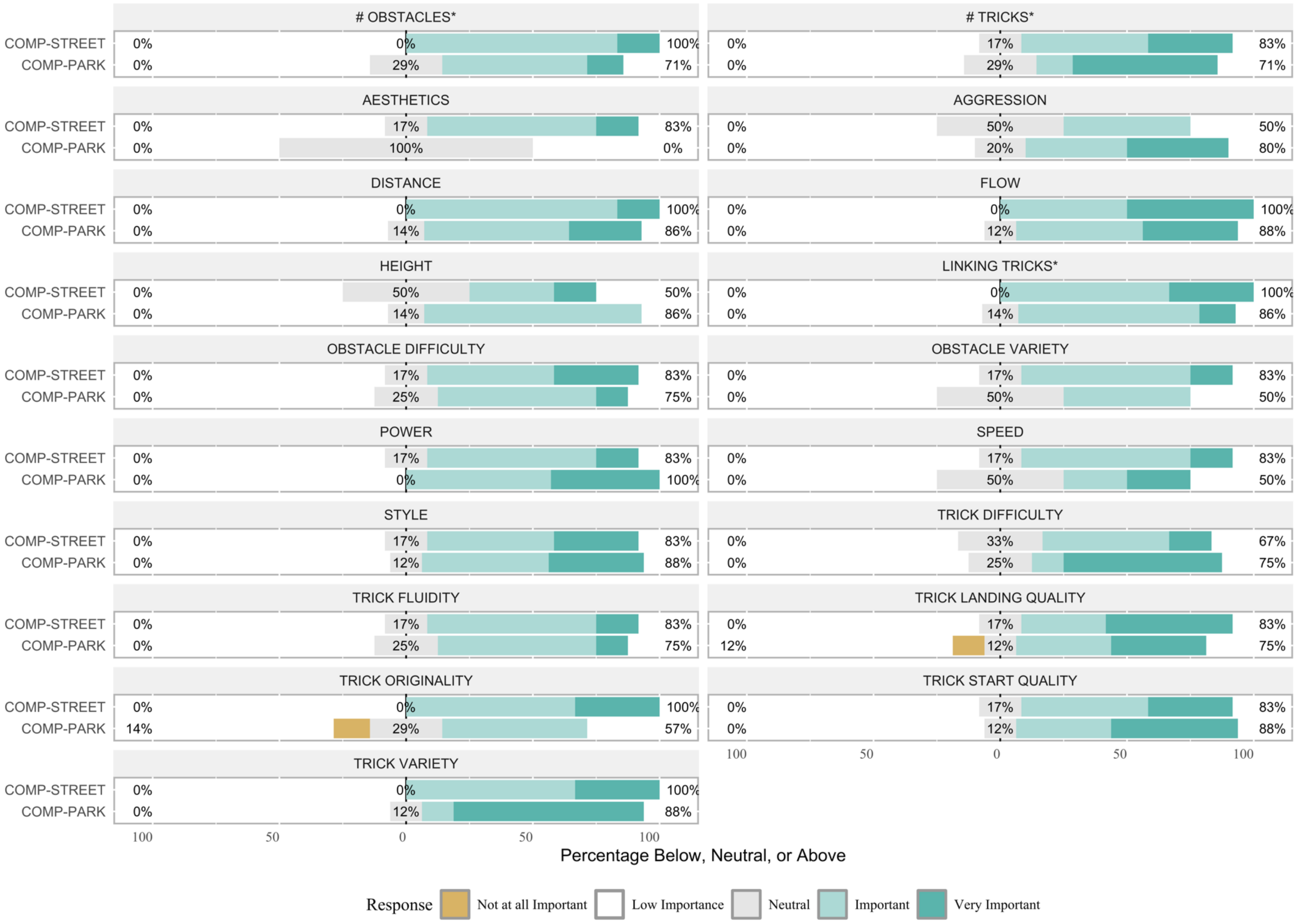


Figure 4: Overall factors and importance level for competitive performance in skateboarding.



* In a street or park run

Figure 5: Overall factors and importance level for competitive performance in skateboarding by competitive discipline; street vs. park.

3.3.3 Training for Performance

When training, skaters most indicated flow (n=30) and style (n=29) as their focus (Figure 6). Seven out of the 33 skaters (21.2%) focused on aggression in training. All ELITE-COMP indicated a training focus on trick originality and variety. Comparatively, only 30% of AMT-COMP participants focused on trick originality. No ELITE-COMP participant indicated a training focus on aesthetics, aggression, or obstacle difficulty. All COMP-STREET (n=6) participants indicated a focus in training on flow, style, and trick variety, compared to 87.5%, 75%, and 62.5% of COMP-PARK, respectively. COMP-PARK participants indicated a focus in training on power (n=6, 75%) and height (n=5, 62.5%), compared to two COMP-STREET (33%).

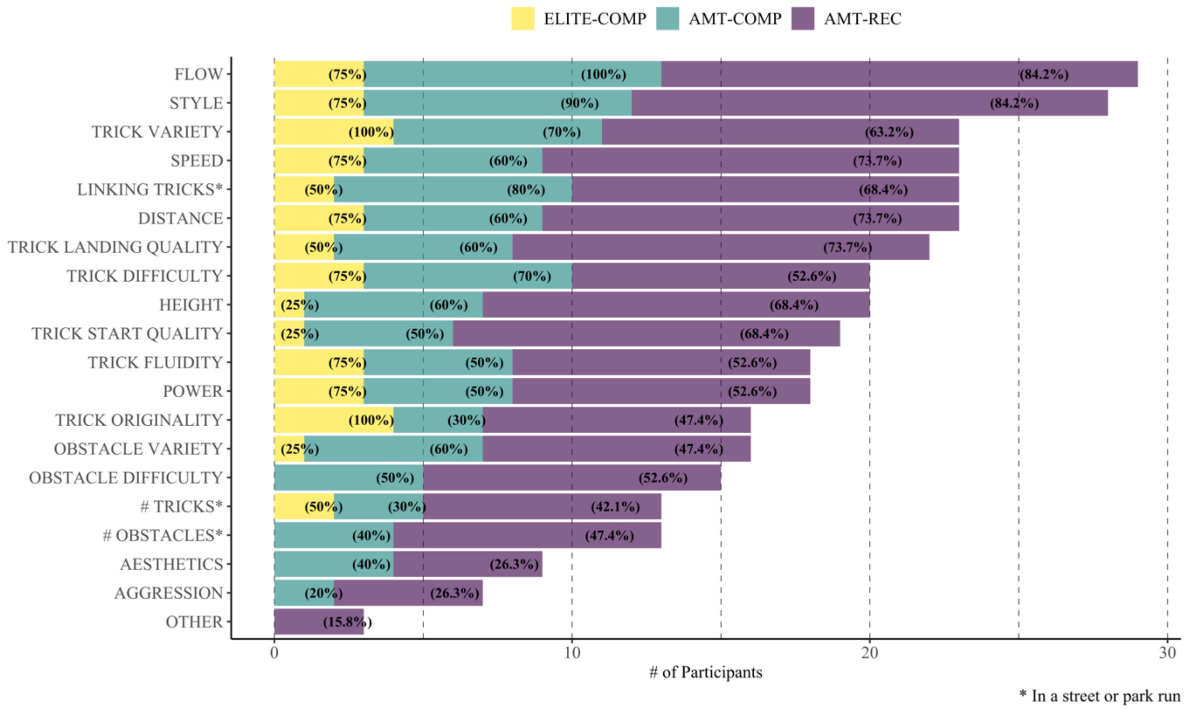


Figure 6: Factors in which skaters focus on the most when training to improve their skateboarding performance (participants were to select all that applied).

3.3.4 Recreational Skateboarding Performance

Half of COMP participants (n=7/14) reported that the importance of various factors for performance differed for recreational skateboarding compared to competitive; three (75%) COMP-ELITE and four (40%) AMT-COMP skaters (COMP-PARK (n=6/8) and COMP-STREET (n=1/6)). The most important factors for recreational skating were consistent with responses regarding competitive skating; flow (n=13) and style (n=11) (Figure 7). All ELITE-COMP participants reported a different factor they felt was the most important for recreational success (trick originality, flow, style, and trick variety).

REC and COMP participants significantly differed with a large effect on the importance of power (W=148.5, p=0.01, r=0.558); power was important or very important to recreational skateboarding for all COMP participants, compared to 61% of REC. Specifically at the amateur level, there was a significant difference and large effect in the importance of power (W=108.5, p=0.03, r=0.571) and medium effect in the importance of aggression (W=72, p=0.03, r=0.379). All AMT-COMP skaters indicated it was important or very important, compared to 53% of AMT-REC.

COMP-PARK skaters found repetition criteria; trick variety (86% COMP-PARK, 50% COMP-STREET) and obstacle variety (57% COMP-PARK, 40% COMP-STREET), more important to recreational skating than COMP-STREET skaters, who placed more importance on speed (100% COMP-STREET, 50% COMP-PARK) and trick difficulty (80% COMP-STREET, 71% COMP-PARK), however, reported quality of landing as not important at all to recreational skating (20% COMP-STREET, 12% COMP-PARK). COMP-STREET skaters also placed importance on aesthetics (100% COMP-STREET, 17% COMP-PARK) and trick originality (80% COMP-STREET, 50% COMP-PARK); 17% of COMP-PARK (0% COMP-STREET) skaters felt trick originality was not important at all. COMP-STREET and COMP-PARK did not significantly differ on any importance level of factors for recreational skating.

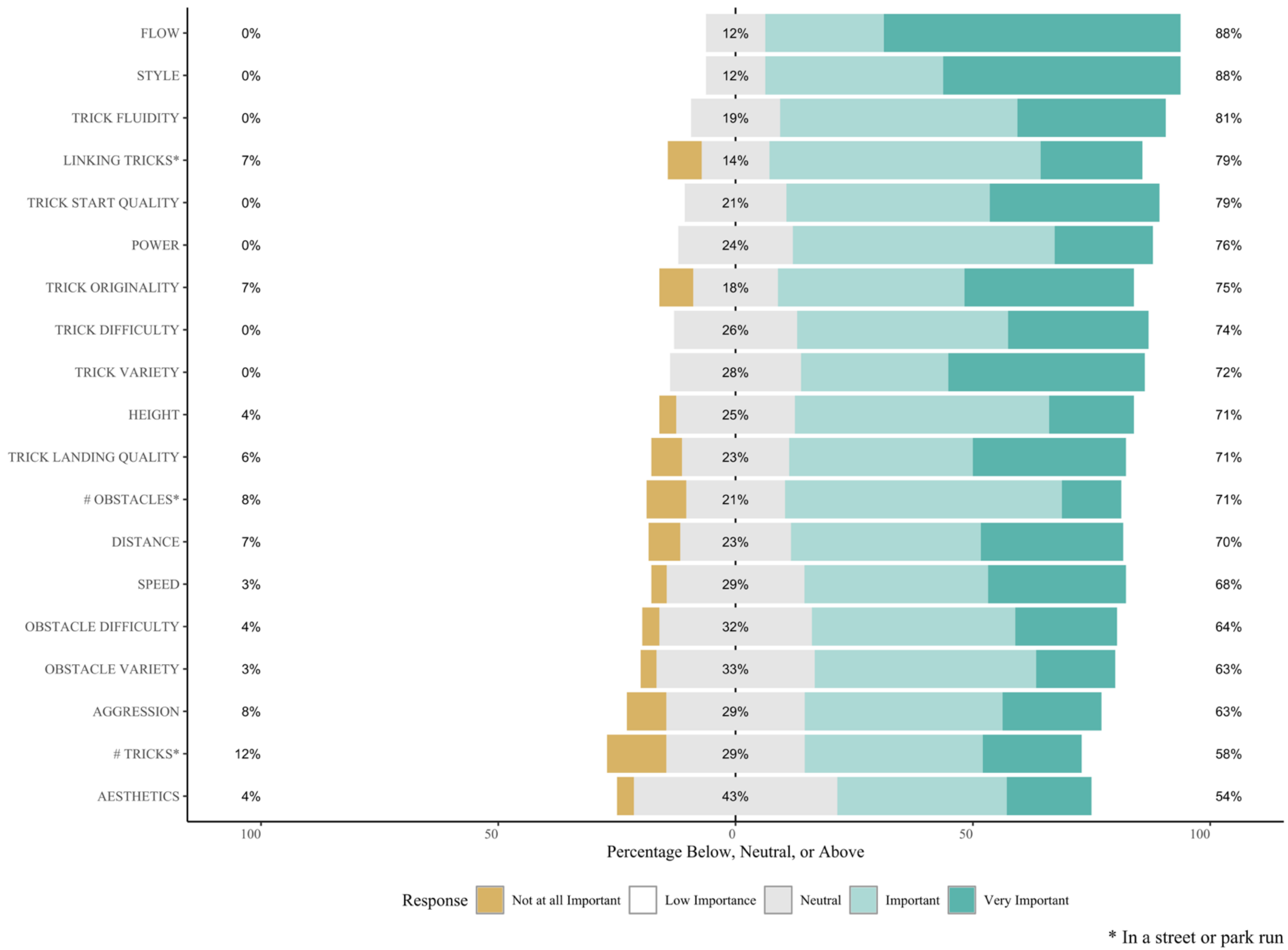


Figure 7: Overall factors and importance level for recreational performance in skateboarding.

3.4 Discussion

A sample of recreational and amateur to elite competitive skaters were surveyed regarding their perceptions of the importance of different performance criteria (World Skate judging criteria) to competitive and recreational street and park disciplines. Overall, flow and style were deemed most important, although differing discipline and skill-specific views within competitive communities indicated some ambiguity. Nonetheless, competitive skaters reported focusing their training on what they deem important to competitive success. Elite skaters focused on originality and variety, while the focus of amateur participants varied. Competitive street skaters highlighted aesthetics and trick originality, whilst park skaters viewed difficulty in selection (trick, obstacle) and execution of tricks (height, power) as more important. Both groups value flow and style when skating for recreation. Moreover, while community values of recreational skating generally align with World Skate's judging criteria, notable discrepancies exist, particularly concerning the emphasis on the number of tricks performed in a run.

World Skate judges apply the same criteria for both street and park skateboarding, as reflected in the shared emphasis on style and flow, which competitive skaters from both disciplines consistently prioritised in this study. However, skaters differed on the importance of underlying style metrics. Street skaters valued aesthetics and trick originality, while park skaters prioritised power, height, and difficulty in both competition and recreational environments. These differences may stem from the physical traits required for each discipline, particularly speed generation. Park skaters rely on pumping and height to maintain speed and perform tricks, requiring strength and power [45, 104]. In contrast, street skaters generate speed through kick-pushing [27] and focus on stylish execution, such as foot placement and board control [21, 22]. Street skaters emphasised aesthetics, with all surveyed skaters agreeing on its importance, whilst park skaters remained neutral, focusing more on difficulty and height. One explanation is that street judges may place more emphasis on originality, whilst park judges prioritise difficulty over originality, as seen in half-pipe snowboarding [105]. These findings suggest that street and park competitions are underpinned by distinct performance criteria, highlighting the need for independent analysis of these disciplines.

Both elite street and park skaters valued speed, but there was less agreement regarding the importance of aesthetics and originality. The criteria defining a more successful aesthetic (or a stylish performance) in competition remain ambiguous and unquantified, however, in recreational skateboarding, research has linked peak performance to a state of "effortless" flow, an appearance of "letting it happen" [106]. This flow state was related to elements of uncertainty, novelty, and experimentation, potentially quantifiable measures of style and flow that were deemed important to elite street success in this survey. Alternatively, previous research also suggests the existence of a distinguishable 'clutch' state in skateboarding, characterised by "making it happen", such as when landing more challenging, higher risk tricks; like the first or last trick in a run or a best-trick attempt [106]. Notably, flow and clutch states require different styles of self-regulation and varying underlying skills [107]. More challenging, higher-risk tricks often require greater speed, power, and height. These factors were particularly valued and prioritised in training by the surveyed elite park skaters. This suggests objective elements of clutch and flow states may capture nuances of park and street skateboarding, including their weighted importance by judges. Thus, future research should explore how quantifiable measures related to clutch and flow states (e.g., novelty of tricks, landing of higher-risk tricks. etc.) relate to street and park judging outcomes so training can be adjusted accordingly. This information would also support the focused development of amateur skaters looking to progress in competition.

Differences in disciplines transfer to training priorities, where street skaters concentrated on flow, style, and variety, and park skaters emphasized power and height. Thus, training practices appear to be closely aligned with what skaters believe to be important for competition. This was further echoed in the differences in perspectives by skill-level. Elite skaters consistently emphasized originality and variety in their training, whereas only a subset of amateur competitors prioritised these aspects. This could be due to amateurs' focus on fundamentals, before attempting to differentiate themselves through originality and variety. Moreover, amateur and elite skaters likely differ in access to resources, competitions, training, and support, which may influence their views on what constitutes performance and their ability to train them. Accordingly, elite sponsored skaters might prioritise factors like technical precision, consistency, and adherence, whilst amateurs may naturally focus more on enjoyment. A clear understanding of how to impress judges at the highest level is needed to ensure coaches can support the development of amateur athletes looking to progress their skating in the competitive realm.

The skaters surveyed placed importance on all of the criteria presented in this survey, suggesting congruence with what World Skate has indicated as essential to elite competitive success (or indeed understanding of the criteria, themselves). However, the level of importance differed both within and between skill levels. For example, each elite athlete suggested a different criterion that was most important in competition, whilst amateur competitors views on performance were relatively homogenous. An argument could be made that skaters selected what they believe judges feel is important to competition success (e.g., how to win). If this is true, this survey shows that these skaters place importance on different aspects of skating when for recreation, possibly suggesting a misalignment between community values of the sport and the criteria by which they are judged in competition. Alternatively, skaters may have responded by selecting criteria they personally believe contribute to 'better' skateboarding (as originally intended). In which case, these are aspects they consider as important and are therefore likely the focus of their training (as indicated in the survey). This may reflect an alignment with World

Skate's overall impression approach, which allows judges to evaluate an entire performance without overemphasising a single facet [97]. In contrast, it may indicate an athlete's bias towards their personal strengths, highlighting the subjectivity inherent in such evaluations. Nevertheless, competitive judging results – an aggregation of multiple judges' overall impressions – do not provide a clear breakdown of an athlete's strengths and weaknesses for each performance. Understanding what constitutes a 'better' performance, including the relative weighting of these criteria, could help skaters and coaches decide on what to emphasise in their training based on their relative strengths and what is important.

Lastly, whilst discipline and skill-level community views on recreational skateboarding generally align with World Skate's competition judging criteria, with all World Skate criteria "neutral to very important" to the majority of participants, notable discrepancies exist, particularly concerning the emphasis on the number of tricks performed in a run. Some skaters (12%) reported number of tricks in a run as not at all important to recreational skating; the strongest negative importance of all performance metrics presented. Nevertheless, all competitive and recreational skaters said it was important for competition success, possibly due to their understanding of the importance placed on this factor by judges. Trick quantity may be crucial for competitive success, but it appears to hold less value in recreational skating. This discrepancy highlights the need for competitive practitioners and skaters to understand how competition demands differ from recreational priorities.

3.4.1 Limitations, Practical Applications, and Future Research Direction

This research provides valuable insights into how elite and amateur street and park skaters perceive and prioritise skateboarding performance criteria in both competitive and recreational contexts. However, we acknowledge the limitations of the small sample size and thus may not have captured the perspectives of the broader skating community; notably, the subset of elite

Olympic skateboarders, and a more encompassing investigation would be warranted. More to this point, future research should look to explore potential sex differences in perception, particularly that of elite female skaters, a group not represented in this study. Nevertheless, the results from this study provide practical findings to implement in an applied setting and guide future research:

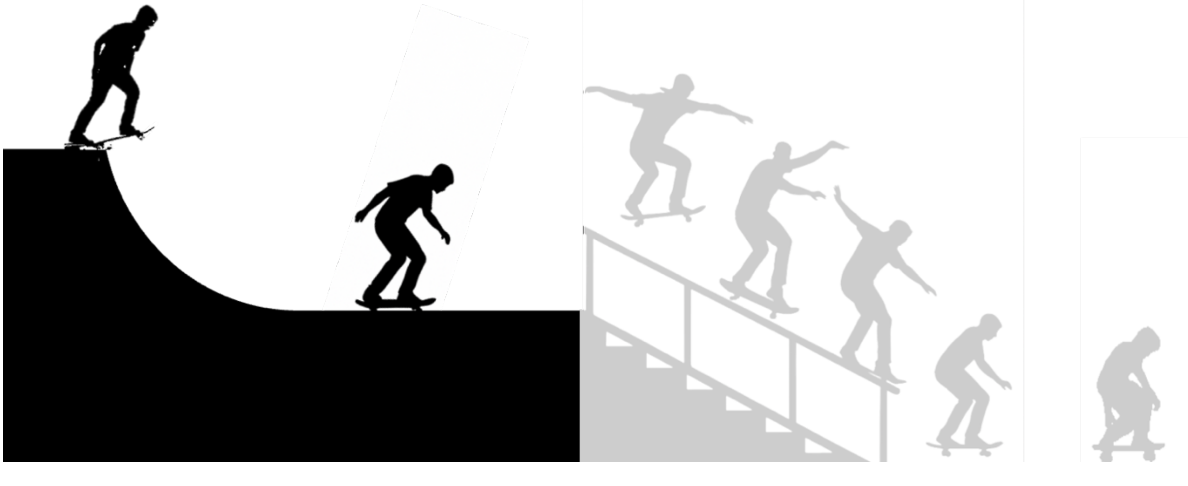
- Future exploration is necessary to determine the relative contribution of different performance criteria to successful outcomes in competition.
- Researchers and practitioners should implement methodologies that capture the distinct characteristics and unique competitive requirements of street and park skateboarding.
- Researchers, practitioners, and skaters should recognise the distinct performance demands of competitive skateboarding compared to recreational skateboarding.
- Underlying objective aspects of flow and style (such as elements of flow and clutch states) should be included in future approaches to better understand the relative importance to competitive success.

3.5 Conclusion

The inherent subjectivity in ranking competitive skateboarding performances introduces ambiguity surrounding what factors lead to success. Findings from this research emphasise disparate views of performance, varying by community involvement, skill level, and discipline. Despite the small sample size, a need for clarity in subjective judging criteria and application in competitive settings is apparent, and future research should implement objective explorations to understand street and park competitive performances, respectively.

SECTION 2: 'GET SET'

DEVELOPING METHODS TO OBJECTIVELY DESCRIBE PERFORMANCE



CHAPTER 4:

DEVELOPMENT AND RELIABILITY OF A STREET SKATEBOARDING NOTATIONAL ANALYSIS FRAMEWORK AND APPLICATION

This chapter comprises the following paper published in *Applied Sciences:*

Diewald, S. N., Noth, N., Mancini, N., Neville, J., Cronin, J. B., & Cross, M. R. (2025). Development and Reliability of a Street Skateboarding Notational Analysis Framework and Application. *Applied Sciences,* 15. 5011. https://doi.org/10.3390/app15095011

Prelude:

In previous chapters, it was intimated that there was an overarching need for clarity regarding the subjective judging criteria utilised in Olympic skateboarding competitions. Aspects of flow and style were reported by the surveyed community in Chapter 3 to be most important for skateboarding performance. Nevertheless, what was considered important for performance differed between competitive and recreational skateboarders, further highlighting the ecological validity concerns raised in Chapter 2. Subjective flow and style were important to performance overall, yet the importance of underlying objective aspects appeared to vary by discipline, skill level, and community involvement. Moreover, whilst gaining community insight is valuable, whether these subjective judgements are reflective of what occurs in practice remains unclear. We now have insight into performance by which we can direct our next steps to investigate what happens ‘in the park’, highlighting the community importance of style and flow. Nevertheless, objective definitions are required to ultimately explore which factors relate to success in competition; unfortunately, no present measurement tool exists. To support future research by capturing underlying elements of subjective judging criteria, like style and flow, a sustainable method by which to do so would need to be developed. Therefore, in Chapter 4 we sought to develop a systematic framework to reliably describe performance aspects of competitive skateboarding. Street skateboarding is the most common and synonymous with ‘skateboarding’ (per Chapter 1) and provided the focus of this chapter. Additionally, the street discipline encompasses a wide range of performance aspects (e.g., tricks, obstacles, competitive formats, etc.) relevant to other disciplines. If found reliable, users could objectively and consistently describe and compare what happens in skateboarding competitions to then understand how this relates to success.

CHAPTER 4: DEVELOPMENT AND RELIABILITY OF A STREET SKATEBOARDING NOTATIONAL ANALYSIS FRAMEWORK AND APPLICATION

4.1 Introduction

Street skateboarding debuted at the Tokyo 2020 Olympic Games and is approved for Los Angeles 2028 after its inclusion in the Paris 2024 Games [96] and consequently, there is an influx of skaters looking to follow the Olympic pathway and compete on the world stage [3]. To effectively support athletes navigating the evolving landscape, we need a comprehensive understanding of performance to identify and enhance the capacities that underpin success [37]. A first step to support street skaters in competition is the objective definition and measurement of aspects of performance, before understanding how success is determined.

In competitive street skating, athletes must interact with obstacles in the environment, performing technical tricks through complex board and body movement [53]. In current competition formats, skaters perform isolated tricks on obstacles (best-trick (BT)) and/or a sequence of tricks linked together around the skatepark (RUN) [98]. Success in Olympic competitions is determined by judges who utilise a set of criteria such as trick and obstacle difficulty, variety, and execution, to award an overall impression score for each attempt to rank performances in that competition round [97]. Whilst some criteria – like execution quality and style – appear subjective, they may have objective underpinnings (e.g., height, speed, or distance travelled) [97] that could be systematically evaluated. However, the subjective application of these criteria, coupled with impression scoring overall, complicates tying specific judging decisions to measurable, targetable, or trainable performance attributes. Accordingly, coaches and athletes lack understanding of performance metrics upon which to train to perform, a fact which is made even more difficult by diverse and evolving competition formats, and the inherent technical complexity and creative variability of tricks performed [108].

Performance analysis (PA) is a systematic process of examining sports performance [29] to provide insights into tactics and strategies [109]. The goal of PA is to capture factors related to how and why outcomes (e.g., winning) occur [43]. PA could be a useful strategy to identify differences between successful and less successful street skateboarding performances [52]. Despite its adoption in many Olympic sports [110], no researchers have yet explored the application of PA approaches in skateboarding. As the tactical demands of competitive skateboarding remain ambiguous [98], a PA system tailored to the unique context of street skateboarding is warranted.

One PA method by which objective performance data can be captured [44] is notational analysis (NA). NA systems are often employed in traditional sports to retrospectively extract spatio-temporal variables to systematically quantify athlete activity from video footage [41]. This method is particularly beneficial when freestyle athlete movement across a large 'field of play' is integral to performance, such as in the board sports surfing [32, 33] and snowboarding [34]. Despite relevance, NA has yet to be fully adopted in skateboarding [108]. However, the growing availability of high-quality broadcast footage (e.g., X-Games and Olympics) and recent validation of video-derived temporal trick metrics [22, 46, 47], supports the use of an NA approach to use broadcast footage to quantify spatio-temporal performance aspects of trick selection, obstacle selection, and execution judging criteria.

Therefore, the aim of this research was to design an NA system and protocol to capture potential outcome-impacting aspects of competitive street skateboarding performance. Additionally, we aimed to test reliability of the system for measuring style-focused spatio-temporal metrics from broadcast footage, leveraging performances during the semi-finals of the 2020 Tokyo Olympics street skateboarding debut.

4.2 Methods

The following section details the design, development, and testing of a custom NA application to quantify aspects of street skateboarding tricks. Although a uniquely built NA tool developed to analyse the Tokyo Olympics street skateboarding competition is described, the overarching NA system and process were designed to be generalisable to other skateboarding competitions and PA software.

A video-based NA application was developed using scatter diagrams, frequency tables, and sequential data collection systems [44] to retrospectively code skateboarding broadcast footage. The construction of an NA system requires consideration of key elements (i.e., player, position, action, time) that are fundamental to all such systems, the intended level of analysis (i.e., team, individual), and how the required information is to be gathered [41]. Therefore, the following sections explore the design of the NA process to record the following key elements: position (obstacle), player (skater), action (trick) and subsequent outcome, and time.

A systematic, mixed-methods approach was used to describe street skateboarding motion. The qualitative approach described by Knudson (2007) was harnessed iteratively – (1) preparation of relevant knowledge using personal experiences, expert opinions, and scientific research, (2) systematic observation, and (3) evaluation of the system to identify weaknesses – and is described in subsequent sections [40].

4.2.1 Participants

The NA system was designed to be used with any street skateboarding competition video footage. To test the aims, publicly available video footage of the 2020 Tokyo Olympic men's and women's street skateboarding competition (https://olympics.com/, access date: 5 March 2022) was used. The data were high-quality (~1080p, 60 frames per s) and formatted for broadcast (e.g., varying camera angles and zoom compiled into a single stream). Only the semi-final round was analysed to capture a consistent range of skill and trick varieties across the men's and women's competitions.

World Skate defines the competition format and rules for Olympic events [97]; however, most street skateboarding competitions follow a similar structure, and as such will be the focus of this paper. Typically, competition format varies by round. In the open qualifier and quarterfinal (preliminary) rounds, skaters often perform only RUNs, taking the best score. In semi-final and final rounds, skaters perform both RUN and BT attempts, with the total number of attempts, score range, and final round score varying depending on the format chosen (e.g., 2/5/4, 2/5/3, etc.). A 2/5/4 format was utilised during the Tokyo 2020 Olympics. In the semi-finals, 4 heats of 5 athletes per sex skated against each other. Skaters performed 2 RUNs of 45 s each, followed by 5 BT attempts, and the top 4 scores (of 7) combined to make the athlete's overall score (2/5/4 format) and ranking for the round. Notably, following the Tokyo Olympics, World Skate transitioned to a 2/5/3 format for street skateboarding, combining the top RUN score and 2 BT scores to form the final round score. Due to it being in its infancy, evolution in the sport is expected; the NA application was designed to accommodate this and any future format changes.

Specific to the Tokyo Olympics, in each heat of the semi-finals, all skaters performed their first RUN before proceeding to their second, followed by a break before beginning the BT attempts in the same fashion. For all RUN and BT attempts, athletes were judged on a point scale from 0.00 to 10.00. Athletes who did not land (bailed) their BT attempt automatically scored a 0.00 for that trick. However, in a RUN, an athlete could bail any number of tricks but continue to attempt to improve their score during the time limit [13]. Demographics and skating characteristics of each skater were retrieved from the World Skate official website (https://www.worldskate.org/skateboarding.html, access date: 5 March 2022).

4.2.2 Key Elements

The process of breaking street skateboarding skill down into its functional parts is an important first analytical step. For all key elements of tricks, a phased approach was used to divide up the trick (movement) into relevant portions such that attention could be focused on the technique (performance) of each [111]. Three phases were identified based on expert knowledge: take-off (TO), event (obstacle interaction) (IA), and landing (LD). This modified three-phase approach follows traditional sports PA [40], which breaks a skill up into preparation, action, and follow-through phases.

4.2.2.1 Position (Obstacle)

A scatter diagram was used to capture the skater's position corresponding to discrete obstacles at each TO, IA, and LD phase per trick attempt (TA) (Figure 8). Then, specific obstacle details and type could be defined and attached to each discrete position in the skatepark. Each skatepark is unique; however, there are design features common across competition fields of play by which obstacles can be defined consistently [112]. For example, skateparks are often developed in a mirrored design to equally accommodate goofy and regular stance skaters [113]. In the dataset for this study, the Tokyo 2020 Ariake Urban Sports Park (Figure 8) was coded, and the full list of obstacles and associated details are available in the online material (https://osf.io/n9bjy/). Most obstacles had a mirrored counterpart on each longitudinal side of the park and "bowl-side" (top of centre, Figure 8) and "stand-side" (bottom of centre, Figure 8) were used to distinguish between the two. All "centre" obstacles, without mirrored counterparts, were labelled as such. More broadly speaking, prior to analysing a competition, standard position/obstacle metrics can be pre-defined, including the following: location within the park (e.g., bowl-side, stand-side, etc.), obstacle type (e.g., flat ground, rail, bank, gap, ledge, quarterpipe, etc.) (Figure 8) and a detailed description unique to that obstacle type (e.g., round rail, square rail, coping, bank to flat, A-Frame hubba ledge, etc.). Then, for a specific skatepark, a unique identifier (obstacle number) for each obstacle can be set; associated with standardised metrics (location, type, description), by which subsequent performance can be compared across parks and competitions. However, notably, a degree of subjectivity is inherent when determining obstacle location, type, and description as described above. Nevertheless, notating position is a compromise between accuracy and having manageable data, and the decision was taken to lean towards the latter, with practical implications in mind, the limitations of which are discussed [44].

Figure 8: Image of Ariake Urban Sports Park from the Tokyo 2020 Olympic Games street skateboarding competition. Numbers represent the unique identifier (obstacle number). Some numbers shown on the screen represent unpictured mirrored (#108, #72, #19) obstacles which are not visible (#123, #125, #126). Mirrored obstacles are represented with those on the top half of the image as “bowl-side” and the bottom half as “stand-side”. Accessed and modified from https://www.skateboarding.worldskate.org/news/1478-tokyo-2020-course-designs.html.

4.2.2.2 Player (Skater)

Player (skater) related metrics were coded once per RUN or BT attempt. Demographics and skating characteristics related to the skater in competition included nationality, age, sex, and preferred stance (goofy or regular). The frequency of coding player meta data will depend on the video length and contents specific to the use case.

4.2.2.3 Action (Trick Attempt)

The most important aspect of defining an action or outcome is ensuring the operational definition of the action is clear and unambiguous [44]. Street skateboarding tricks were grouped to allow for subjective interpretation of style, encompassing athletes' individualisation and nuanced trick variations in a way where trick difficulty and variation could be assessed. Regarding the action, a "trick attempt" (TA) was defined when a skater popped the board to perform a movement with the board and/or obstacle, and then subsequently attempt to land on the board. The NA application allowed for the ability to code a free text trick name (common skateboarding nomenclature) associated with each TA ($trick_{TA}$). All tricks where a skater popped their board (any number of wheels left the ground) were considered TAs; however, kick-turns or reverts alone, such as to change direction, were not considered a TA, but rather a "redirection", coded but removed from any analysis (as noted). Of importance, in skateboarding a redirection is often used to set the skater's position and stance before the next trick, with a matter of intent by the skater. To avoid subjectivity in what TAs to include or not, all movements where any number of wheels left the ground were coded, including potential redirection tricks, such as fundamental stalls often performed on quarterpipe coping (50–50 stalls, rock to fakie). Thus, selected potential redirection tricks could be filtered out during post-processing if desired, ensuring generalisability to suit a practitioner's specific needs.

A best trick (BT) TA was a single trick, and a RUN was made up of consecutive TAs. For this analysis, each TA encompassed the three phases: TO, IA, and LD (

Table 10). For each phase, stance (regular, switch, fakie, nollie), skater rotation amount (degrees) and body rotation direction (front-side (FS), back-side (BS)), obstacle approach direction (FS, BS), trick category (fundamental, flip, grind/slide, air/grab/stall, balance, freestyle, or not applicable), and category trick name (e.g., ollie, crooked grind, boardslide, etc.) were recorded (

Table 11). The pre-defined lists used for this analysis and all coded TAs from the semi-finals competition are in the online material (https://osf.io/n9bjy/). To note, the three-phase approach was selected to encompass the vast majority of street skateboarding tricks at the time [114]. However, as the sport inevitably evolves, this process could accommodate more than three phases, possibly through the inclusion of sub-phases.

Table 10: List and definitions of notational analysis acronyms

Trick	Acronym	Description (Example from Tokyo Olympics semi-finals)
Trick Attempt	TA	Skater pops board and performs movement(s) to interact with board and/or obstacle. Broken into TO, IA, and LD phases. TA naming aligns with skateboarding nomenclature. (e.g., TA name: Half Cab + FS Noseslide + Varial Heelflip)
Best-Trick Attempt	BT	Single TA; Multiple BT TAs are often performed in a competition round. (e.g., 5 BT TAs)
Run Attempt	RUN	Timed attempt, made up of any number of consecutive TAs; Multiple RUNs often performed in a competition round. (e.g., 45-second, 2 RUNs per skater)
Trick Phase – Take-off	TO	Period from pop of board to start of event/interaction (IA) phase. Skaters will not always perform a trick during this period; like when popping the board in a different stance (e.g. nollie). However, to increase trick difficulty, skaters will often rotate or flip into IA phase grinds/slides. (e.g., **Half Cab** + FS Noseslide + Varial Heelflip)
Trick Phase – Event (Interaction)	IA	Period from start to end of 'obstacle' interaction (e.g. grind/slide). In case of a flip trick, this would be airtime of flip trick. (e.g., Half Cab + **FS Noseslide** + Varial Heelflip)
Trick Phase – Landing	LD	Period from end of obstacle interaction until landing. Like TO, might only include landing (no tricks), but often skaters will rotate or flip out of event phase grinds/slides. (e.g., Half Cab + FS Noseslide + **Varial Heelflip**)

TA trick attempt; *FS* front-side; *BT* best-trick; *TO* take-off; *IA e*vent/interaction; *LD* landing;

Table 11: List of trick attempt coded key elements (action, outcome, position, time) and associated descriptions.

	TA: Associated Feature Name (*Acronym*)	Feature Description	Example
Attempt	Attempt Type	Whether TA occurs during RUN or BT	RUN or BT
	Attempt Number	Sequential order of RUN or BT attempt	RUN=1 or 2 BT=1, 2, 3, 4, or 5
Trick Attempt (TA) Level	TA Number	Sequential order of TAs	RUN=1, 2, 3, …+ BT=1
	Trick Name *($trick_{TA}$)*	Skateboarding nomenclature (common street trick name)	e.g., Half Cab + FS Noseslide + Varial Heelflip
Phase Level – Take-off (TO)	TO Stance *($stance_{TO}$)*	Stance skater pops board to perform TA	Regular, switch, nollie, or fakie
	TO Trick Type *($trick\text{-}type_{TO}$)*	Trick type category describing movement during TO phase	Fundamental, flip, grind, slide, air/grab/stall, balance, freestyle, or not applicable
	TO Trick Name *($trick_{TO}$)*	Skateboarding nomenclature for trick during TO	e.g., Ollie, Nollie, Half Cab, Cab, BS 180, etc.
	TO Obstacle Number *($obstacle_{TO}$)*	Obstacle skater pops board from during TO; Predetermined obstacle type *($obst\text{-}type_{TO}$)* and description *($obst\text{-}desc_{TO}$)* associated	e.g., 1, 2, …131
Phase Level –Event/Interaction (IA)	IA Stance *($stance_{IA}$)*	Stance during IA phase movement (typically same as TO stance)	Regular, switch, nollie, or fakie
	IA Trick Type *($trick\text{-}type_{IA}$)*	Trick type category describing movement during IA phase	Fundamental, flip, grind, slide, air/grab/stall, balance, freestyle, or not applicable
	IA Trick Name *($trick_{IA}$)*	Skateboarding nomenclature describing movement performed during IA phase	e.g., BS Boardslide, 360 Flip, Tail Stall, etc.
	IA Obstacle Number *($obsaclet_{IA}$)*	Obstacle skater interacts with (TA on/with/over/etc); Predetermined obstacle type *($obst\text{-}type_{IA}$)* and description *($obst\text{-}desc_{IA}$)* associated	e.g., 1, 2, …131
Phase Level	LD Stance *($stance_{LD}$)*	Stance skater lands in; typically, regular or fakie; if $stance_{TO}$ and	Regular, switch, or fakie

	$stance_{IA}$ are both switch, $stance_{LD}$ is also switch	
LD Trick Type *(trick-type$_{LD}$)*	Trick type category describing movement during LD phase	Fundamental, flip, grind, slide, air/grab/stall, balance, freestyle, or not applicable
LD Trick Name *(trick$_{LD}$)*	Skateboarding nomenclature describing additional movement, if any, during LD phase	e.g., Kickflip, BS 180, etc.
LD Obstacle Number *(obstacle$_{LD}$)*	Obstacle skater lands on to end TA; Predetermined obstacle type *(obst-type$_{LD}$)* and description *(obst-desc$_{LD}$)* associated	e.g., 1, 2, …131

TA trick attempt; *BT* best-trick; *TO* take-off; *IA* event/interaction; *LD* landing; *FS* front-side; *BS* back-side;

The level (attempt, trick attempt, phase) that these features are coded is included to show hierarchy

4.2.2.4 Subsequent Outcome(s)

The outcome of a TA was defined as; 1) whether the skater landed or bailed the TA, and 2) the judges' scores (RUN score, BT score, and/or round score). A TA was considered landed when the skater rolled away for at least 1 second following the attempt [13]. If the skater used their hands during the landing but still managed to roll away, this was considered landed, unless otherwise noted by the judges (BT TA scored 0). Moreover, outcome timing was captured as whether a bail occurred during the TO, IA, or LD phase. During a bailed TA, all data that was available up to the bail phase was recorded.

4.2.2.5 Time

Competition timing was captured for each TA by the skater's heat number, heat order (sequence within the heat), and round. Then, using frame-by-frame video analysis, TAs were identified by where they occurred sequentially (TA number) during a RUN or BT attempt. For each TA, 4 distinct time points (frames) were coded: take off ($Frame_{TO}$), event/interaction start ($Frame_{IA\text{-}Start}$), event/interaction end ($Frame_{IA\text{-}End}$), and landing ($Frame_{LD}$) (Table 12). These time points represent the key moments of the start and end of each phase [111]. Then temporal features were calculated for each timing phase using frame selections: TO time ($Time_{TO}$), IA time ($Time_{IA}$), LD time ($Time_{LD}$), and TA time ($Time_{TA}$) (Table 13, Figure 9). Frame selection and associated time were of particular interest in this study, as the metrics offer insight into estimating skateboarding performance (e.g., airtime, grind time).

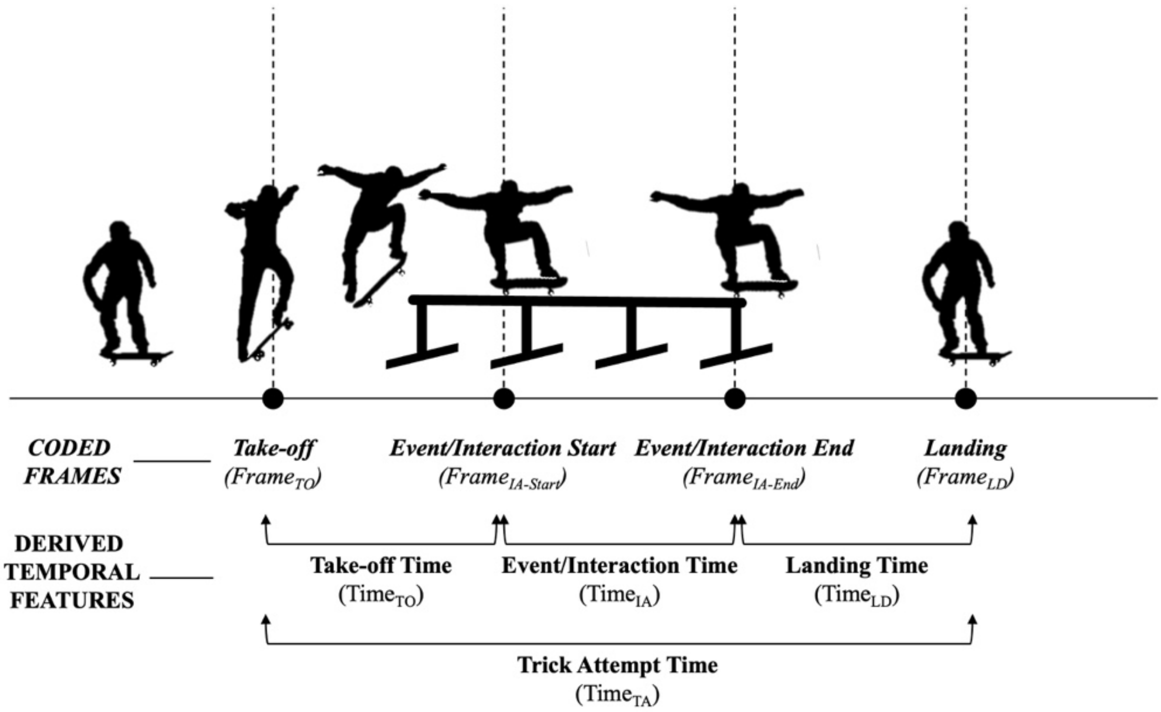


Figure 9: Coded frames and derived temporal features

Table 12: Definitions and examples of time points per trick attempt to guide frame selection

obstacle$_{IA}$ and TO - IA Transition[a]	TA Distinct Time Points: Take-Off *(Frame$_{TO}$)*	Interaction Start *(Frame$_{IA\text{-}Start}$)*	Interaction End *(Frame$_{IA\text{-}End}$)*	Landing *(Frame$_{LD}$)*
obstacle$_{IA}$ = Not Applicable TAs that only interact with obstacles during TO and LD (not IA) (e.g., fundamental, flip, air/grab, balance)	Frame prior to board completely leaving ground (no contact of wheels with ground)	Same as *Frame$_{TO}$*	Same as *Frame$_{LD}$*	First frame all wheels contact ground
obstacle$_{IA}$ = Applicable; Clear TO - IA TAs that interact with obstacle (other than air) during IA phase (e.g., grind, slide, stall)		Frame before first contact of board (wheels/trucks) with obstacle (typically start of grind/slide)	Frame before last contact of board (wheels/trucks) with obstacle (typically end of grind/slide)	
obstacle$_{IA}$ = Applicable; NOT Clear TO - IA TAs that interact with obstacle (other than air) during IA phase, but no clear frame where IA phase starts/stops; typically redirection or potential redirection tricks like quarterpipe "coping tricks" (e.g., BS/FS 50-50 stall, FS 5-0, Fakie Tail Stall, Rock to Fakie, etc.)	Frame before board appears to rotate or first set of wheels goes over coping	Frame before first contact of board (wheels/trucks) with obstacle (typically first contact of trucks with quarterpipe coping)	Frame before last contact of board (wheels/trucks) with obstacle (typically last contact of trucks with quarterpipe coping)	First frame all wheels contact ground (quarterpipe transition)

TA trick attempt; *TO* take-off; *IA* event/interaction; *LD* landing; *BS* back-side; *FS* front-side;
[a] Frame selection guided by classification of obstacle$_{IA}$ and visibility of transition from TO phase to IA phase

4.2.3 Procedures

4.2.3.1 Data Preparation and Notational Analysis

To capture potential outcome-related aspects of street skateboarding, a custom NA application was designed using MATLAB (MathWorks Inc. (2021b). MATLAB version: 9.11.0 (R2021b), Natick, MA, USA: The MathWorks Inc.) (Figure 10). Importantly, the NA framework we present is independent from this software, and the system could be implemented using other platforms or tools. Broadcast footage was clipped into separate videos for each BT and RUN, and subsequently loaded into the application, featuring two video viewing windows, each displaying the video selected (A) from the file selection panel (B) and the trick selection panel (C), respectively. The trick selection panel was accompanied by buttons for frame selection (D), and a panel for trick and obstacle classification (E). The application included buttons for TA tagging (F) and an athlete details panel (G). Attributes related to that BT or RUN clip were entered (skater and select action attributes). Then, each individual TA was tagged (as above) (F), and a trimmed video clip (H) was created capturing one second before and after the TA frame. A rater could then label each TO, IA (start and end), and LD phase, respectively, capturing action (E), position (J), and outcome metrics (K) to identify that TA. For intra-rater reliability, one rater (R1) coded all video clips on two occasions ($R1_1$ and $R1_2$), at least two weeks apart. For inter-reliability, three raters (R1, R2, and R3) coded all video clips in a different order. Specifically, raters coded TAs in alphabetical order by skater first name (or reverse alphabetical order). Thus, each coded all TAs from an individual skater before moving on to another skater.

Trick classification was conducted independently by two authors, who were experienced in classifying skateboarding tricks, skaters themselves for at least 5 years, and were familiar with skating terminology. The reliability of trick naming and coding was not assessed; however, any disagreements in trick classification or TA outcome (e.g., whether hand drag during RUN TA was landed or bailed) were discussed together and final decisions and underpinning reasonings were provided in the discussion.

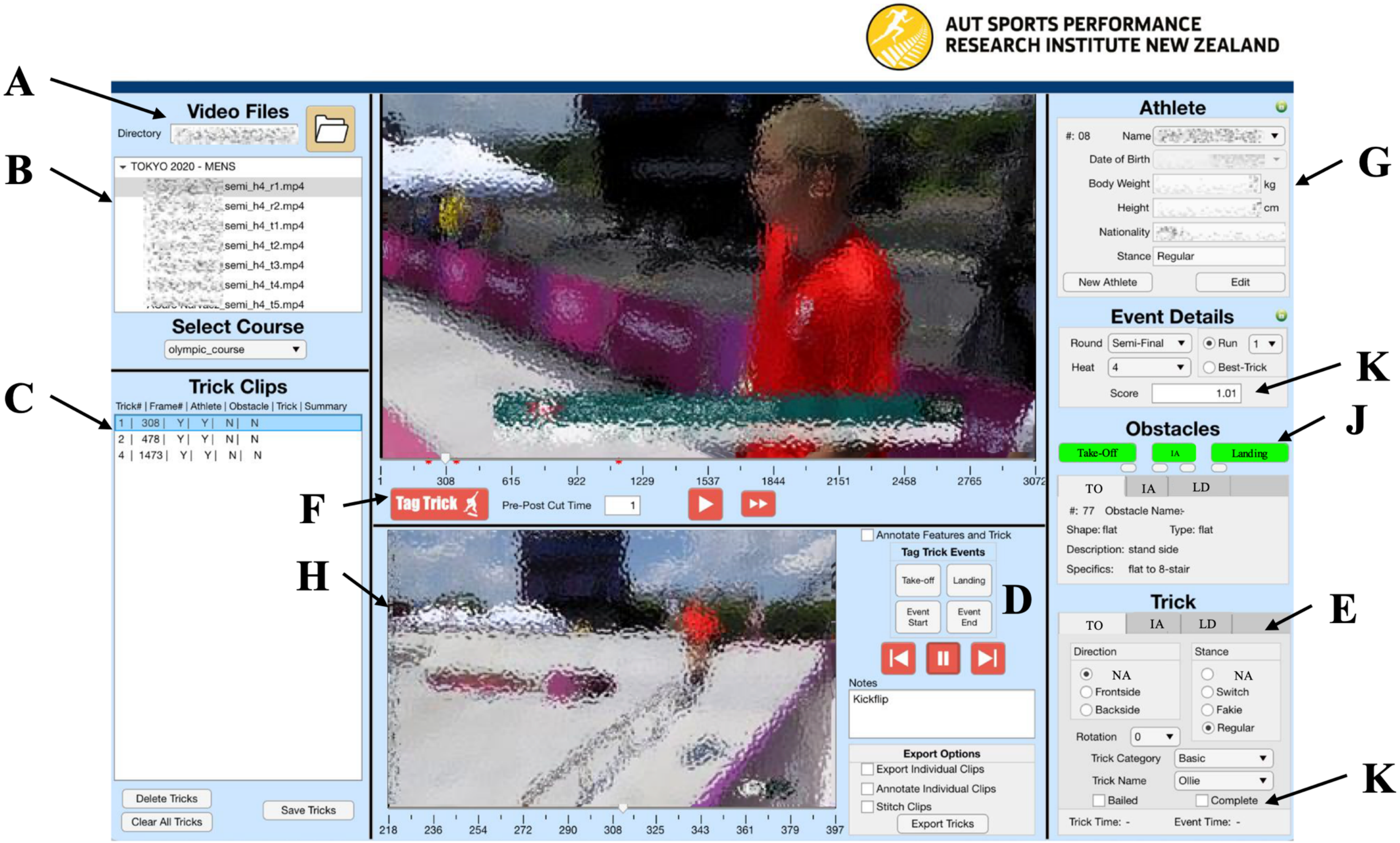


Figure 10: Example of a custom MATLAB notational analysis application to code street skateboarding trick attempts.

4.2.3.2 Post-Processing and Feature Engineering

All TAs and associated coded attributes were exported (as csv) (each TA as a row, with position, action, and outcome attributes as columns) and imported into R Statistical Software (RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/) to calculate select features (e.g., trick type grouping features) (Table 13). Derived features were selected to encompass trick and obstacle difficulty and variety.

Table 13: Derived trick attempt feature definitions and associated acronyms

	Derived Features (acronym, if applicable) *(Variable Type)*	Description	Equations and Associated Coded Attributes[b]
TA Features	TA Trick Type ($trick\text{-}type_{TA}$) *(Factor)*	Combination of all phase trick types ($trick\text{-}type_{TO}$, $trick\text{-}type_{IA}$, $trick\text{-}type_{LD}$) to create unique $trick\text{-}type_{TA}$; if phase trick type was 'not applicable', it was removed[a]	$\textit{trick-type}_{TA} = trick\text{-}type_{TO} + trick\text{-}type_{IA} + trick\text{-}type_{LD}$
	Combination Trick *(Boolean)*	Whether skater combines more than one trick through flipping or rotating (body and/or board) into and/or out of grind (>180 degrees), slide, air/grab/stall, balance, freestyle $trick\text{-}type_{IA}$	IF $trick\text{-}type_{TA}$ contains "+" → Combination Trick = TRUE
	Flip In and/or Out (Flip In/Out) *(Boolean)*	Whether skater flips board into and/or out of grind, slide, balance, freestyle, air/grab/stall trick (e.g., combination trick)	IF [$trick\text{-}type_{TO}$ | $trick\text{-}type_{LD}$ = Flip AND $trick\text{-}type_{IA}$=grind | slide | balance | freestyle | air/grab/stall] → Flip In/Out=TRUE

	Obstacle Type (obst-type$_{TO, IA, LD}$) *(Factor)*	Stair, flat, rail, bank, gap, ledge, bank, or quarterpipe	Predetermined by obstacle$_{TO}$, obstacle$_{IA}$, obstacle$_{LD}$
TA Phase (TO, IA, LD) Obstacle Features	Obstacle Description (obst-desc$_{TO,TA/IA, LD}$) *(Factor)*	Detailed description related to obstacle type: **Rail:** round rail, square rail, etc. **Stair:** 12-stair, 5-stair, etc. **Bank:** banked hip, bank to gap, etc. **Ledge:** A-frame hubba, inclined hubba, etc. **Quarterpipe:** coping, transition, etc.	obst-desc$_{TA}$ = obst-desc$_{IA}$ (predetermined by obstacle$_{TO}$, obstacle$_{IA}$, obstacle$_{LD}$)
	Park Side (obst-side$_{TO, TA/IA, LD}$) *(Factor)*	Side of skatepark obstacle is located: stand-side (mirrored) OR bowl-side (mirrored) OR centre (not-mirrored)	obst-side$_{TA}$ = obst-side$_{A}$ (predetermined by obstacle$_{TO}$, obstacle$_{IA}$, obstacle$_{LD}$)
	Mirrored Obstacle Number *(Factor)*	If obstacle is located on stand-side or bowl-side (not centre), a mirrored obstacle number is created to reflect same obstacle on opposite side (e.g., # - #)	Predetermined by obstacle$_{TO}$, obstacle$_{IA}$, obstacle$_{LD}$

TA Temporal Features	Take-off Time ($Time_{TO}$) *(Numeric)*	Time from board pop to start of IA phase; time to reach obstacle; typically 'air-time (in)'	$Time_{TO} = Frame_{IA\text{-}Start} - Frame_{TO}$ If trick-type$_{A}$ is aerial based trick (not grind, slide, or stall) $\rightarrow$ $Time_{TO}$ = not applicable
	Event / Interaction Time ($Time_{IA}$) *(Numeric)*	Time on obstacle; 'air-time' (for aerial tricks), 'grind/slide/stall time', 'manual time', etc.	$Time_{IA} = Frame_{IA\text{-}End} - Frame_{IA\text{-}Start}$
	Landing Time ($Time_{LD}$) *(Numeric)*	Time from last interaction with obstacle to landing; corresponds to 'air-time (out)' (e.g., if skater flips out of grind/slide/stall, $Time_{LD}$ is air-time related to that flip trick)	$Time_{LD} = Frame_{LD} - Frame_{IA\text{-}End}$ If trick-type$_{IA}$ is aerial based trick (not grind, slide, stall) $\rightarrow$ $Time_{LD}$ = not applicable
	Trick Attempt Time ($Time_{TA}$) *(Numeric)*	Time from board pop to landing	$Time_{TA} = Time_{LD} - Frame_{TO}$ If TA is not a Combination Trick and trick-type$_{TA}$ is fundamental, air (not grab), flip, balance, or manual $\rightarrow$ $Time_{TA} = Time_{IA}$

TA trick attempt; *TO* take-off; *IA* event/interaction; *LD l*anding; *obst* obstacle;

[a] Ollie, Nollie, Switch Ollie were not considered fundamental trick types and were removed; for example, trick type of Nollie Kickflip is 'Flip', not 'Fundamental + Flip'

[b] Coded attributes from custom notational analysis application including pre-determined obstacle metrics (obstacle type, obstacle description, and park-side) for TA phases (TO, IA, LD)

4.2.4 Statistical Analyses

All statistical analyses were performed using R. Notably, we used *tidyverse* [102], *easystats parameters* [115], and the *boot* package [116]. For all analyses, redirection tricks were removed (acid drop (n=1 male TA, n=1 female TA), kick-turns (n=24 male TAs, n=22 female TAs)). Unless otherwise noted, potential other redirection tricks such as coping tricks (e.g., BS 50-50 stalls) were included for consistency. Descriptive frequency analysis was used to present a high-level summary of the data, using derived TA temporal features from a single rater (R1).

The intra-rater and inter-rater reliability of both TA coded frame selection ($Frame_{TO}$, $Frame_{IA\text{-}Start}$, $Frame_{IA\text{-}End}$, $Frame_{LD}$) and derived temporal features were quantified ($Time_{TO}$, $Time_{IA}$, $Time_{LD}$, $Time_{TA}$) (e.g., $Time_{TO}$ could be influenced by the choice of two separate frames, $Frame_{TO}$ and/or $Frame_{IA\text{-}Start}$). Specifically, intra-rater and inter-rater reliability of coded frame selection were assessed using mean absolute differences (MAD) overall and broken into different group comparisons based on sex (male, female), obstacle type ($obst\text{-}type_{TO,\ TA,\ LD}$), and trick type features (grind vs. slide, combination vs. non-combination) (Table 13). Groupings based on preferred stance (regular, goofy), $stance_{TO}$, obstacle location ($obst\text{-}side_{TO,\ TA,\ LD}$), and obstacle descriptions ($obst\text{-}desc_{TA}$) for rails (square, round) and ledges (A-frame hubba, hubba) were explored but not presented here due to uneven sample size. Bootstrapped (1000 samples) 95% confidence intervals (CI) were also calculated. To calculate MAD for inter-rater reliability between three raters, the process involved spreading each metric across different raters (R1, R2, R3) to enable pairwise comparisons. The absolute differences between raters (R2-R1, R3-R1, R3-R2) was calculated for each TA. MAD was then computed by averaging the absolute differences between each pair. The approach for intra-rater reliability was the same, but for two rater timepoints ($R1_1$-$R1_2$). Using TA times from previous literature [22], based off a static ollie airtime of 0.38 seconds (0.18m), MADs<3 frames (0.05 seconds at 60 Hz) were considered 'acceptable' for TA coded frames (<15% of a static ollie). This level of granularity was presumed essential for capturing subtle performance differences in skateboarding tricks, as even small timing variations can significantly impact execution [21].

The intra-rater and inter-rater reliability of derived temporal features were assessed using intraclass correlation (ICC) (Table 13, Figure 9); adopting a two-way, single measurement/rater, absolute agreement and consistency models, with random and mixed effects respectively [117]. Values of ICC>0.9 were interpreted as high variable reliability for derived temporal features, with attention paid to the lower bound of the 95% CI (e.g., ≥ 0.7).

Bland Altman (BA) analyses were used to assess intra-rater and inter-rater consistency for both coded frame selection and derived temporal features. BA mean differences (MD) and 95% limits of agreement (LoA) were used to evaluate agreement and consistency between pairs of raters (R2-R1, R3-R1, R3-R2) and rater timepoints ($R1_1$-$R1_2$), respectively.

4.3 Results

4.3.1 Descriptive Analysis

Forty skaters (20 males, 20 females) competed in the semi-finals, representing 18 different countries. The average age was 22.9±5.2 years (male=24.2±4.3, female=21.5±5.7). There were 19 regular (male=11, female=8, n=366 TAs) and 21 goofy (male=9, female=12, n=434 TAs) stance skaters. TAs were popped in all stances: 83% regular, 6.12% fakie, 5.5% nollie, and 5.38% switch ($stance_{TO}$).

Skaters attempted 27 different $trick\text{-}type_{TA}$ (https://osf.io/n9bjy/), of which 20 were combination tricks (flip-in=4, flip-out=5). Slides (n=327) and grinds (n=221) encompassed 68.5% of TAs. Seven $trick\text{-}type_{TA}$ were only attempted once and 16 $trick\text{-}type_{TA}$ were attempted five or less times. Moreover, 13 $trick\text{-}type_{TA}$ were attempted by a single skater only. Skaters interacted with 101 out of the possible 131 labelled obstacles in the park (Figure 8).

The semi-finals encompassed 80 RUN and 200 BT attempts. After removing selected redirection tricks, 800 TAs (male=426, female=374) remained for the descriptive analysis of performance. After further removing 196 bailed TAs, 604 TAs (BT=94, RUN=510) remained, from which reliability was evaluated. The nature of the broadcast footage caused some key TA events to be partially or completely unobserved, leading to data missing not at random [118]. Subsequently, listwise deletion was utilised for reliability analyses, deleting 44 TAs ($Frame_{TO}$), 38 TAs ($Frame_{IA\text{-}Start}$), 38 TAs ($Frame_{IA\text{-}End}$), and 44 TAs ($Frame_{LD}$) missing frames, respectively. As such, sample sizes varied. After listwise deletion, 593 TAs (male=324, female=269) remained, encompassing 98 coping TAs, of which 22 (3.7%) (male=13, female=9) were labelled as potential redirection coping tricks (e.g., axel stalls). Summary statistics for derived temporal features from these TAs are provided in Table 14.

Table 14: Summary statistics of derived temporal features (seconds) from landed trick attempts during the semi-finals round of the Tokyo 2020 Olympics street skateboarding competition

Derived Temporal Features	**Summary Statistics**[a]	
	Coping Tricks *Included*[b] *(n=593)*	**Coping Tricks *Excluded*[c]** *(n=495)*
$Time_{TA}$	0.843±0.217	0.815±0.188
$Time_{TO}$	0.355±0.119	0.385±0.105
$Time_{IA}$	0.316±0.146	0.302±0.12
$Time_{LD}$	0.23±0.085	0.215±0.061

TA trick attempt; *TO* take-off; *IA* event/interaction; *LD* landing;

[a] Values are presented as mean ± standard deviation (number of TAs)
[b] Coping tricks (kick-turns) have been removed, but additional assumed redirection tricks (e.g. axel stalls) are included
[c] All coping tricks and potential redirection tricks have been removed

4.3.2 Reliability

Intra-rater frame selection was reliable (MAD<3 frames, ICC>0.7), whilst inter-rater reliability varied (MAD=1.55 to 4.35 frames, ICC=0.38 to 0.96). Only $Frame_{LD}$ selection was acceptable for inter-rater reliability. However overall, inter-rater consistency was higher than agreement, particularly for $Time_{IA}$ (Table 15). Based on ICC thresholds, only $Time_{TA}$ was found reliable between raters (consistency and agreement). BA results for inter-rater and intra-rater reliability are presented in Table 16.

Table 15: Intra-rater and inter-rater reliability (agreement and consistency) of coded frames and derived temporal features (seconds) during the semi-finals round of the Tokyo 2020 Olympics street skateboarding competition

Coded Temporal Frames	**MAD [95% CI[a]]**	
	Intra-Rater	**Inter-Rater**
$Frame_{TO}$	1.43 [1.29, 1.56] (n=586)	3.82 [3.66, 3.97] (n=489)
$Frame_{IA\text{-}Start}$	2.26 [2.08, 2.46] (n=586)	4.35 [4.07, 4.63] (n=489)
$Frame_{IA\text{-}End}$	2.04 [1.85, 2.24] (n=586)	3.62 [3.4, 3.85] (n=489)
$Frame_{LD}$	1.33 [1.21, 1.47] (n=586)	1.55 [1.45, 1.68] (n=489)

Derived Temporal Features	**ICC [95% CI] (n=# TAs)**			
	Intra-Rater		**Inter-Rater**	
	Agreement	**Consistency**	**Agreement**	**Consistency**
$Time_{TA}$	0.97 [0.96, 0.98] (n=586)	0.97 [0.97, 0.98] (n=586)	0.91 [0.65, 0.96] (n=488)	0.96 [0.95, 0.97] (n=488)
$Time_{TO}$	0.87 [0.84, 0.89] (n=443)	0.87 [0.85, 0.89] (n=443)	0.62 [0.56, 0.68] (n=376)	0.64 [0.59, 0.68] (n=376)
$Time_{IA}$	0.87 [0.84, 0.89] (n=408)	0.87 [0.85, 0.89] (n=408)	0.63 [0.38, 0.77] (n=355)	0.73 [0.69, 0.77] (n=355)
$Time_{LD}$	0.73 [0.66, 0.78] (n=448)	0.74 [0.7, 0.78] (n=448)	0.38 [0.26, 0.48] (n=378)	0.43 [0.37, 0.49] (n=378)

TA trick attempt; *TO* take-off; *IA* event/interaction; *LD l*anding,; *MAD* mean absolute differences; *ICC i*ntra-class correlation coefficient; *CI* confidence interval;

Values *include* all coping tricks (e.g., potential redirection tricks such as axel stalls), but *exclude* redirection tricks (e.g., kick-turns)

[a] Bootstrapped confidence interval (n=1000 samples)
[b] Number of TAs for derived features may vary due to missing data from raters and specific trick type nuances.

Table 16: Intra-rater and inter-rater Bland-Altman analysis of coded frames and derived temporal features (seconds) from landed trick attempts during the semi-finals round of the Tokyo 2020 Olympics street skateboarding competition

Coded Frames and Derived Temporal Features	**BA Mean Difference (frames, seconds) [95% LoA] (n=# TAs)[a]**			
	Intra-Rater	**Inter-Rater**		
	$R1_1$-$R1_2$[b]	**R2-R1[c]**	**R3-R1**	**R3-R2**
$Frame_{TO}$	-0.55 [-6.75, 5.65] (n=586)	-4.72 [-10.53, 1.09] (n=489)	-5.04 [-9.56, -0.53] (n=489)	-0.32 [-5.21, 4.57] (n=489)
$Frame_{IA\text{-}Start}$	-0.14 [-6.62, 6.34] (n=586)	-3.55 [-17.29, 10.19] (n=489)	-3.48 [-10.38, 3.42] (n=489)	0.07 [-14.78, 14.92] (n=489)
$Frame_{IA\text{-}End}$	-0.14 [-6.75, 5.65] (n=586)	2.71 [-9.19, 14.61] (n=489)	1.52 [-6.57, 9.61] (n=489)	-1.19 [-11.77, 9.39] (n=489)
$Frame_{LD}$	0.23 [-3.79, 4.26] (n=586)	0.97 [-4.46, 6.39] (n=489)	-0.35 [-4.61, 3.9] (n=489)	-1.32 [-6.34, 3.71] (n=489)
$Time_{TA}$	0.01 [-0.08, 0.11] (n=586)	0.09 [-0.04, 0.23] (n=488)	0.08 [-0.03, 0.18] (n=488)	-0.02 [-0.13, 0.09] (n=488)
$Time_{TO}$	0.01 [-0.1, 0.12] (n=443)	0 [-0.23, 0.24] (n=376)	0.03 [-0.09, 0.16] (n=376)	0.03 [-0.21, 0.27] (n=376)
$Time_{IA}$	-0.01 [-0.15, 0.14] (n=408)	0.14 [-0.12, 0.4] (n=355)	0.07 [-0.11, 0.25] (n=355)	-0.07 [-0.36, 0.21] (n=355)
$Time_{LD}$	0.02 [-0.1, 0.13] (n=448)	-0.05 [-0.2, 0.1] (n=378)	-0.04 [-0.19, 0.12] (n=378)	0.02 [-0.13, 0.17] (n=378)

TO take-off; *IA* event/interaction; *LD l*anding; *BA* Bland Altman; *LoA* limits of agreement;
Values *include* all coping tricks (e.g., potential redirection tricks such as axel stalls), but *exclude* redirection tricks (e.g., kick-turns). Intra-rater reliability was assessed between two timepoints (denoted with subscript) by a single rater (R1), and inter-rater reliability was assessed between two different raters of three individuals (R2-R1, R3-R1, and R3-R2).

[a] Number of TAs; [b] Intra-rater (R1) time points (1 and 2) [c] Inter-rater individual raters (1, 2 and 3). R1 is the same as the intra-rater.

4.3.2.1 Intra-Rater Reliability

There was strong intra-rater consistency across all frame selections (BA: MD<1 frame, LoA<±7 frames) (Table 16). Intra-rater reliability of frame selection for all groups was high (MAD 95% upper limit<3 frames) (Table 17). Of all frame selections, sex differences in reliability were highest for $Frame_{TO}$; slightly less reliable for male TAs (MAD=1.67 [1.48, 1.85]) than female TAs (MAD=1.12 [0.95, 1.33]), and less consistent (BA MD [95% LoA]: male=-1 [-5.35, 3.34], female=0.01 [-3.77, 3.79]). All frame selections were least reliable for quarterpipe/coping obstacle interactions ($obst\text{-}type_{TO}$, $obst\text{-}type_{IA/TA}$, $obst\text{-}type_{LD}$) (Table 17). $Frame_{IA\text{-}End}$ selection was less reliable for grinds (MAD=2.38) than slides (MAD=1.43).

Table 17: Intra-rater reliability of coded frames from landed trick attempts during the semi-finals round of the Tokyo 2020 Olympics street skateboarding competition

Grouping		MAD [95% CI][a] (n=# TAs)[b]			
		$Frame_{TO}$	**$Frame_{IA\text{-}Start}$**	**$Frame_{IA\text{-}End}$**	**$Frame_{LD}$**
Sex	Male	1.67 [1.48, 1.85] (n=322)	2.42 [2.16, 2.65] (n=322)	2 [1.75, 2.28] (n=322)	1.43 [1.27, 1.61] (n=322)
	Female	1.12 [0.95, 1.33] (n=264)	2.06 [1.79, 2.36] (n=264)	2.08 [1.81, 2.38] (n=264)	1.21 [1.02, 1.43] (n=264)
Trick Type[d]	Grind	1.4 [1.13, 1.7] (n=174)	2.44 [2.1, 2.8] (n=174)	2.38 [1.99, 2.8] (n=174)	1.16 [0.93, 1.39] (n=174)
	Slide	0.97 [0.83, 1.13] (n=214)	1.94 [1.71, 2.17] (n=214)	1.43 [1.24, 1.66] (n=214)	0.98 [0.85, 1.11] (n=214)
	Combination	1.27 [1.04, 1.5] (n=131)	2.08 [1.73, 2.5] (n=131)	2 [1.57, 2.48] (n=131)	1.18 [0.97, 1.39] (n=131)
	Non-Combination	1.47 [1.31, 1.65] (n=455)	2.31 [2.09, 2.54] (n=455)	2.05 [1.84, 2.28] (n=455)	1.38 [1.22, 1.55] (n=455)

Obstacle Type[c]	Ledge	–	1.98 [1.69, 2.27] (n=120)	2 [1.63, 2.43] (n=120)	–
	Stair	–	1.46 [0.96, 2.04] (n=26)	0.88 [0.5, 1.42] (n=26)	–
	Quarterpipe	2.97 [2.56, 3.48] (n=102)	3.72 [3.13, 4.36] (n=102)	3.63 [2.93, 4.4] (n=102)	2.56 [2.09, 3.05] (n=98)
	Rail	–	2 [1.77, 2.21] (n=219)	1.59 [1.39, 1.81] (n=219)	–
	Bank	1.19 [1.01, 1.35] (n=243)	1.45 [1.08, 1.84] (n=49)	1.53 [1.18, 1.94] (n=49)	1.26 [1.05, 1.47] (n=143)
	Gap	–	2.93 [1.8, 4.31] (n=45)	2.13 [1.33, 3.07] (n=45)	–
	Flat	0.94 [0.78, 1.11] (n=212)	0.96 [0.57, 1.35] (n=23)	1.74 [1.22, 2.48] (n=23)	0.98 [0.85, 1.1] (n=324)
	Roll	1.59 [1.1, 2.07] (n=29)	–	–	1.57 [1.1, 2.14] (n=21)

TA trick attempt; *TO* take-off; *IA* event/interaction; *LD* landing; *CI* confidence interval;

Values presented by skateboarding specific groupings: sex, grind or slide, combination trick, and obstacle type and *includes* all coping tricks (e.g., potential redirection tricks such as axel stalls), but *excludes* redirection tricks (e.g., kick-turns). Corresponding obstacle types determined for respective coded frame selection: Frame_{TO} ~ obstacle_{TO}, $\text{Frame}_{IA\text{-}Start/End}$ ~ $\text{obstacle}_{IA/TA}$, Frame_{LD} ~ obstacle_{LD}.

'–'=Not applicable

[a] Bootstrapped CI (n=1000 samples)

[b] Number of TAs may vary across grouping and derived feature due to missing data from raters and specific trick type nuances

[c] Obstacle type corresponds to TA phase (e.g., Frame_{TO} ~ obstacle_{TO}, $\text{Frame}_{IA\text{-}Start}$ ~ $\text{obstacle}_{IA,}$ etc.)

[d] Only grind and slide trick types included to encompass majority of TAs involving an obstacle interaction

4.3.2.2 Inter-Rater Reliability

Frame selection inter-rater reliability for all groups had a MAD 95% upper limit greater than the 3-frame threshold. Only $Frame_{LD}$ was acceptable and most consistent across all rater combinations, however this was not the case when involving quarterpipes (MAD Upper CI<2 frames) (Table 18). Additionally, of all the groups, $Frame_{IA\text{-}Start}$ onto a ledge, and $Frame_{IA\text{-}End}$ off stairs or rails, and out of slides (MAD Upper CI<3.1 frames) were reliable. The lowest consistency occurred during $Frame_{TO}$ and $Frame_{IA\text{-}Start}$ selection between R3-R1 and R2-R1 (BA MD ranged from -3.48 to -5.04), however consistency between R2-R3 was much higher (BA MD<1 frame) (Table 16). The reliability of $Frame_{IA\text{-}Start}$ and $Frame_{IA\text{-}End}$ was better for female TAs (MAD=$Frame_{IA\text{-}Start}$: 3.68 [3.43, 3.95], $Frame_{IA\text{-}End}$: 3.04 [2.82, 3.28]) than males TAs (MAD= $Frame_{IA\text{-}Start}$: 4.95 [4.5, 5.41], $Frame_{IA\text{-}End}$: 4.15 [3.82, 4.54]). In addition, selecting $Frame_{IA\text{-}Start}$ was more reliable for non-combination tricks (MAD=3.92 [3.7, 4.17]) than combination (MAD=5.84 [4.94, 6.8]), and most reliably selected when on a ledge (obst-$type_{IA/TA}$) (MAD=2.61 [2.22, 3.04]). Alternatively, selecting $Frame_{IA\text{-}End}$ was more reliable off a rail (MAD=2.38 [2.2, 2.57]) compared to a ledge (MAD=3.35 [3.03, 3.68]).

Table 18: Inter-rater reliability of coded frames from landed trick attempts during the semi-finals round of the Tokyo 2020 Olympics street skateboarding competition

Grouping		MAD [95% CI][a] (n=# TAs)[b]			
		$Frame_{TO}$	$Frame_{IA\text{-}Start}$	$Frame_{IA\text{-}End}$	$Frame_{LD}$
Sex	Male	3.45 [3.25, 3.65] (n=256)	4.95 [4.5, 5.41] (n=256)	4.15 [3.82, 4.54] (n=256)	1.68 [1.53, 1.83] (n=256)
	Female	4.22 [4, 4.43] (n=233)	3.68 [3.43, 3.95] (n=233)	3.04 [2.82, 3.28] (n=233)	1.42 [1.26, 1.59] (n=233)
Trick Type[d]	Grind	3.91 [3.67, 4.16] (n=151)	3.45 [3.04, 3.89] (n=151)	3.8 [3.46, 4.13] (n=151)	1.47 [1.28, 1.68] (n=151)
	Slide	3.65 [3.44, 3.87] (n=187)	3.92 [3.42, 4.46] (n=187)	2.15 [2.01, 2.31] (n=187)	0.97 [0.87, 1.09] (n=187)
	Combination	3.2 [2.93, 3.45] (n=108)	5.84 [4.94, 6.8] (n=108)	3.67 [3.11, 4.25] (n=108)	1.16 [1, 1.33] (n=108)
	Non-Combination	3.99 [3.82, 4.16] (n=381)	3.92 [3.7, 4.17] (n=381)	3.61 [3.38, 3.83] (n=381)	1.67 [1.54, 1.8] (n=381)

Obstacle Type[c]	Ledge	–	2.61 [2.22, 3.04] (n=102)	3.35 [3.03, 3.68] (n=102)	–
	Stair	–	3.82 [2.42, 5.58] (n=19)	2.11 [1.65, 2.61] (n=19)	–
	Quarterpipe	4.03 [3.61, 4.42] (n=78)	5.79 [5.13, 6.44] (n=78)	7.23 [6.34, 8.24] (n=78)	3.61 [3.24, 4.04] (n=75)
	Rail	-	4.16 [3.68, 4.64] (n=197)	2.38 [2.2, 2.57] (n=197)	–
	Bank	4.03 [3.81, 4.25] (n=209)	5.52 [4.86, 6.29] (n=43)	3.19 [2.6, 3.81] (n=43)	1.71 [1.47, 1.96] (n=118)
	Gap	–	5.48 [4.67, 6.4] (n=31)	4.86 [4.05, 5.74] (n=31)	–
	Flat	3.49 [3.27, 3.7] (n=180)	5.92 [4.75, 7.33] (n=17)	3.69 [2.82, 4.65] (n=17)	0.95 [0.86, 1.03] (n=280)
	Roll	3.73 [3.09, 4.42] (n=22)	–	–	1.42 [1.08, 1.75] (n=16)

TA trick attempt; *TO* take-off; *IA* event/interaction; *LD* landing;

Values presented by skateboarding specific groupings: sex, grind or slide, combination trick, and obstacle type and *includes* all coping tricks (e.g., potential redirection tricks such as axel stalls), but *excludes* redirection tricks (e.g., kick-turns). Corresponding obstacle types determined for respective coded frame selection: $Frame_{TO}$ ~ $obstacle_{TO}$, $Frame_{IA\text{-}Start/End}$ ~ $obstacle_{IA/TA}$, $Frame_{LD}$ ~ $obstacle_{LD}$.

'–'=Not applicable

[a] Bootstrapped CI (n=1000 samples)

[b] Number of TAs may vary across grouping and derived feature due to missing data from raters and specific trick type nuances

[c] Obstacle type corresponds to TA phase (e.g., $Frame_{TO}$ ~ $obstacle_{TO}$, $Frame_{IA\text{-}Start}$ ~ $obstacle_{IA}$, etc.)

[d] Only grind and slide trick types included to encompass majority of TAs involving an obstacle interaction

4.4 Discussion

A NA system and protocol were designed to capture outcome-impacting aspects of competitive street skateboarding performance and applied it to broadcast footage from the Tokyo Olympics. Overall, intra-rater reliability for the expert rater was good, with no notable differences in reliability across groupings (trick and obstacle types, or time durations). Frame selection and derived temporal feature reliability varied with obstacle types (rails, ledges, quarterpipes) and trick types (grinds/slides, combination/non-combination). Specifically, the reliability of obstacle interaction frames ($Frame_{IA\text{-}Start}$, $Frame_{IA\text{-}End}$) and associated performance times ($Time_{IA}$, $Time_{TO}$, $Time_{LD}$) were the most impacted, with longer durations being less reliable.

Overall, the PA approach and associated NA system developed demonstrated acceptable reliability of key TA event frame selection (MAD < 2 frames) by a single, experienced rater. In contrast, inter-rater reliability was considerably lower, albeit better when judged as consistency versus agreement; for example, the lower bounds of total trick attempts and interaction time increased to 0.95 (from 0.65) and 0.69 (from 0.38), respectively, when using a consistency model. Acceptable intra- and inter-rater reliability had been observed in technical sports previously, such as with jump height from 2D video footage of gymnastics vaulting [119]. This might suggest that the extra complexity of the skater–skateboard–obstacle interaction with the inconsistency of broadcast footage potentially impacts reliability. Also, more experience and familiarity with the NA system might improve reliability, with a single, experienced rater being preferable in practice. However, insights can be provided from the inter-rater reliability results as to what specifically may impact a rater's ability to reliably code skateboarding metrics.

Building on these observations, a more detailed breakdown of reliability reveals important nuances between frame selection and timing measurements. Take-off and landing frames were more reliably selected than frames influenced by obstacle interaction. Moreover, trick time, derived from take-off to landing, exhibited the highest reliability. A possible explanation is that movements occurring over shorter durations, such as the pop, provide less room for variability in frame selection. The clear definitions and nature of these movements, typically starting from flat or inclined ground, make it easier to distinguish the frame when wheels leave the ground. Thus, temporal features derived from broadcast footage of tricks in the transition should be limited to interaction time, to avoid using unreliable take-off and landing frames.

In contrast, identifying the start and end of obstacle interactions, such as with rails or ledges, was less reliable. Initial contact of the board or wheel trucks was visually less distinct, and longer durations between take-off and the obstacle interaction further decreased reliability. This is likely due to more complex movements of the board and skater, such as combination tricks, which tend to be more dynamic and create visually complex scenarios that make pinpointing the start of the obstacle interaction more difficult. These limitations could possibly be mitigated by utilising a 'zoom' feature or higher resolution footage (e.g., sharper videos).

Obstacle interaction reliability also decreased with longer interaction times. This relationship appears to be influenced by aspects of trick difficulty and variety. The duration of obstacle interaction often equates to the grind/slide time, and skaters increase this via distance along the obstacle and/or by decreasing speed. Although obstacle length was not controlled, it is postulated that reduced speeds (e.g., increased interaction time) confounded selecting the point of clearing an obstacle. For example, if females performed more grinds than slides, on more ledges than rails, and at reduced speeds, this might explain the reduced reliability of the selected end interaction frame from grinds and ledges, compared to slides and rails. Differences in skateboarding performance metrics is an interesting topic for future study. Nevertheless, practitioners should exercise caution when attempting to use temporal performance metrics derived from broadcast video [120], particularly when comparing tricks of different difficulties and obstacle varieties.

The raters in this study were familiar with PA, but the primary rater was extremely habituated in the use of the NA system for skateboarding applications. Ultimately, the accurate identification and consistent classification of street tricks require attuned skateboarding-specific knowledge. This necessity poses a limitation for future research, as the interpretation and classification of complex tricks may vary between raters with different levels of expertise. Moreover, the current approach employs both subjective (trick names and types) and objective (rotation amount and direction) classification of tricks. Notably, in this study, the reliability of trick naming and coding was not assessed, which is a crucial element of an NA system [121]. This is likely a topic for future researchers and ultimately practitioners to explore. Given the multitude of variables captured by the system, if a similar system is desired to be used reliably, it is essential to apply skateboarding-specific knowledge to select the most relevant aspects of performance for analysis. The authors believe a transition from subjective trick naming to more objective trick attributes will be critical for advancing efficient and practical PA. An aligned, evidence-based approach to grouping may help reduce time costs and move towards an objective end of trick classification continuum. For example, it is suggested that future NA users define standardised trick types to group together tricks of similar style, difficulty, and execution. This approach will ensure the data collected provides meaningful and ecologically valid insights into competitive performance.

Using this NA application, 800 TAs were coded from the Tokyo Olympics. Of these, 595 were analysed, and thus would have feasibly been useable for other purposes (e.g., in practice in quantifying aspects of performance). It is important to note that some trick attempts were excluded due to footage limitations, often missing a clear visual of the wheels and/or obstacle due to the camera angle. This represents a limitation of relying on public broadcast footage for detailed PA and could signal a challenge for practitioners. However, the NA approach developed is not limited to broadcast footage, and reliability may improve with other methods of video collection. For example, an additional 'side-on' camera view may improve the visibility and reliability of obstacle interaction frame selection, as opposed to an aerial view. More to this point, this analysis also revealed that frame selection and derived time metrics for quarterpipe and coping tricks were not reliable, likely due to the lack of a clearly visible pop and landing. The lack of clarity in determining these events using this NA system challenges utility in overall trick counts, particularly when considering the impact on judges' overall impression. Similar issues have been addressed in snowboarding and surfing [33, 34] and might provide useful insights for refining the NA system in skateboarding, such as consolidating the metrics coded; for example, removing obstacle IA time phases, and replacing them with a system to directly measure the vertical or horizontal speed of movement.

4.4.1 Limitations, Practical Applications, and Future Research Direction

A rater's ability to use the application to accurately capture and quantify performance elements (critical aspects of trick selection, obstacle selection, and execution) is directly related to experience and familiarity with skateboarding. The selection of raters in this research meant the interpretations were somewhat limited. A more homogenous sample of raters familiar with street skateboarding may be useful for future research exploring reliability of such a system. In street skateboarding, tricks are given names depending on the movements performed by the skater and board interacting with an obstacle. However, naming tricks is nuanced in the community, such that the same trick can have many names (e.g., treflip vs. 360 flip). In addition, many tricks appear very similar (nosegrind vs. crooked grind) and are potentially only distinguishable by the intention of the rider. Therefore, to understand if tricks can be consistently and reliably identified across raters, future research should investigate the validity of trick classification.

To provide effective and practical insight into strategy, it is essential to capture events in enough detail to replicate the interacting elements that could affect each action and outcome [9]. However, to ensure the NA process can be conducted efficiently and reliably between raters, future research should look to consolidate the number of coded metrics and standardise trick classification prior to extracting specific key performance differentiators (rather than the current approach of trick naming and subsequent feature engineering of performance related metrics). One such solution could be to explore trick families to reduce the number of trick types. Additionally, the system should be used on other competitions of various skill levels and skateparks to ensure its generalisability. However, when doing so, particular attention should be given when categorising obstacles to ensure consistency and applicability across skate parks.

4.5 Conclusion

This study evidenced the successful implementation of a PA approach within skateboarding that facilitates uniquely defining skateboarding trick attempts. Accordingly, this approach allows users to quantify performance aspects of judging criteria, including subjective elements of style, without sacrificing skateboarding nomenclature. Whilst the approach shows promise, caution should be used when extracting temporal features from broadcast footage. Future researchers should look to leverage this PA method to understand the technical and tactical demands of street skateboarding before understanding the underlying physical capacities required to be successful.

SECTION 3: 'SEND IT'

APPLYING METHODS TO CHARACTERISE AND DISTINGUISH PERFORMANCE

CHAPTER 5:

SKATEBOARDING'S OLYMPIC DEBUT: A COMPARATIVE ANALYSIS OF THE MEN'S AND WOMEN'S STREET COMPETITION

This chapter comprises the following paper *in review* for publication in the *International Journal of Sports Science and Coaching:*

Diewald, S. N., Mancini, N., Noth, N., Neville, J., Cronin, J. B., & Cross, M. R. (2025). Skateboarding's Olympic Debut: A Comparative Analysis of the Men's and Women's Street Competition. *International Journal of Sports Science and Coaching, In review*.

Prelude:

Chapter 4 focused on the development and implementation of a method to classify actions and measure performance aspects of street skateboarding competitions, and reflects on aspects of its use moving forward, including reliability. A first step towards understanding performance is using the framework developed to describe what happens in a given competition. Accordingly, the broad and accessible coverage of world-class skateboarding at the Tokyo Olympics offered a unique opportunity to gain insight into performance at the highest level. Although competition formats and scoring have slightly shifted since the Olympic debut and undoubtedly performance has evolved since, the judging criteria has remained the same. Moreover, judges ranked men's and women's divisions on the same scale. This presents a unique opportunity by which to directly compare performances between sexes. So, the aim of Chapter 5 was to utilise the custom NA framework developed in Chapter 4 to describe characteristics of elite street skateboarding and compare scores across divisions. This will be the first time competitive skateboarding will be objectively quantified, and the first to explicitly recognise the men's and women's divisions as separate competitions. The findings of this chapter will serve as an initial step towards understanding performance and practically how further analysis might be approached.

CHAPTER 5: SKATEBOARDING'S OLYMPIC DEBUT: A COMPARATIVE ANALYSIS DESCRIBING THE MEN'S AND WOMEN'S STREET COMPETITION

5.1 Introduction

Street skateboarding debuted at the Tokyo 2020 Olympic Games and it's approval for Paris 2024, Los Angeles 2028, and beyond suggests that sporting governing bodies have developed a standardised and adaptable foundation by which competition can sustainably evolve [96]. With this in mind, for athletes to succeed on the competitive stage, and coaches to support development and team selection, they need a clear understanding of performance [28]. However, little is known regarding tactical demands of competition nor its physical or technical determinants [98]. A first step to support street skaters in competition is the objective definition and measurement of performance and understanding how athletes score in their competitive environment.

In Olympic street skateboarding, skaters must negotiate a course containing a range of small and feature obstacles, the latter of which are larger, mimicking the urban street environment (e.g., rails, stairs, ledges, etc.). Specifically, competition consists of two attempt formats: Run (RUN) attempts, in which skaters link together a sequence of trick attempts (TA) around the park, and best-trick attempts (BT), in which skaters attempt single, isolated tricks (TA) typically of the highest difficulty. Success is determined by judges who utilise World Skate criteria to award an overall impression score for each BT and RUN attempt, by which to rank the skaters' performance in that competition round [97]. These standardised criteria purportedly encompass subjective and objective aspects of trick and obstacle variety, difficulty, and style [13]. Nonetheless, anecdotally the inherent subjectivity of skateboarding performance renders it complicated to objectively determine what distinguishes and constitutes success. No research exists in the area, and how judges apply the criteria and their relative weighting towards scoring is unknown.

In the Tokyo Olympic competition, a “2/5/4” format was utilised, where the top “4” attempt scores from “2” RUNs and “5” BTs were added together to form a skater’s total round score. All RUN and BT attempts were judged on a point scale from 0.00 to 10.00. Athletes who did not land (bailed) their BT attempt automatically scored a 0.00 for that trick. In a RUN, an athlete who bailed a trick could continue to score during the allotted time limit [53]. Thus, a single overall impression score was awarded, encompassing all TAs, landed or bailed, within a RUN. Whilst aspects like this complicate the direct allocation of scores to specific TA performance, objectively measuring what skaters do in Olympic street skateboarding competitions is a crucial next step to understand RUN and BT performances and how underlying aspects relate to overall impression scores. Notational analysis (NA) provides a means of feasibly quantifying and exploring these factors.

Both Olympic men (M) and women (W) street skaters compete on the same course, and the divisions are judged utilising the same criteria [11]. Moreover, at the Tokyo Olympics, it appeared that judges utilised the same scale across divisions to score attempts, evidenced by a much higher average round score for the men’s medal winners (36.23±0.92), compared to the women (14.8±0.41) [122]. However since, the sport has evolved, and at the 2024 Paris Olympics, male and female scores converged (M=280.52±0.99, W=264.02±9.83) [123] under a new “2/5/3” format, scoring attempts from 0.00 to 100.00. Whether the convergence is due to scaling, underlying performances, or both, is unclear. Nonetheless, the standardised approach to judging at the Tokyo Olympics provides a unique opportunity to explore sex-based performance differences, in addition to the underlying reasons associated with RUN and BT attempt scores.

The development of new and reliable notational analysis (NA) approaches [108] and broadly accessible high-quality footage provides a unique avenue for analysing and subsequently enhancing the understanding of skateboarding performance in elite athletes. Utilising this approach, the aim of this study was to characterise elite street skateboarding by comparing judge awarded scores of men's and women's RUN and BT attempts from the Tokyo Olympics and conduct exploratory analysis to describe any differences.

5.2 Methods

5.2.1 Experimental Approach to the Problem

In this study, we utilised a customised NA framework and application [124] to quantify, describe, and subsequently compare performance aspects of elite men's and women's street skateboarding, using footage from the 2020 Tokyo Olympics.

5.2.2 Participants

The participants in this study were street skaters who competed at the 2020 Tokyo Olympics. Demographics and skating characteristics of each skater were retrieved from the World Skate official website (https://www.worldskate.org/skateboarding.html, access date: 05 March 2022). A total of 40 athletes (20 M, 20 W) representing 18 countries (12 M, 13 W) skated at the Games. Skaters were regular (11 M, 8 W) and goofy-stanced (9 M, 12 W) with an average age of 22.9±5.2 years (M=24.2±4.3, W=21.5±5.7). Since the underlying footage was publicly available, no explicit consent from participants nor ethical approval was required from our university board.

5.2.3 Procedures

5.2.3.1 Data Collection

For this project we leveraged publicly available video footage of the 2020 Tokyo Olympics men's and women's street skateboarding competition, including semi-finals and finals rounds (https://olympics.com/, access date: 05 March 2022). Videos were high-quality (~1080p, 60 frames per second) and formatted for broadcast (e.g., varying camera angles and zoom compiled into a single stream). A total of 392 attempts were analysed from the competition, consisting of 112 RUN and 280 BT attempts. Both the men's and women's divisions respectively completed 56 RUN attempts (40 in the semi-finals, 16 in the finals) and 140 BT attempts (100 in the semi-finals, 40 in the finals).

5.2.3.2 Notational Analysis

NA on footage was conducted in accordance with the methods presented by Diewald, Noth [124]. Briefly, the custom NA application and associated tagging process was conducted on individual TAs during skater RUN and BT attempts. Each TA encompassed three phases: take-off (TO), event/interaction (IA), and landing (LD). Trick classification, including common nomenclature trick names, was conducted independently by two authors, who were experienced in classifying skateboarding tricks, skaters themselves (>5 years), and familiar with skating terminology. Any disagreements in trick classification or TA outcome (e.g., whether hand drag during RUN TA was landed or bailed) were discussed together and final decisions were presented in the discussion, if applicable.

All TAs and associated coded NA attributes were exported (as a .csv file, each TA as a row, with position, action, and outcome attributes as columns) and imported into R Statistical Software (RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/) to derive features (e.g., trick type grouping features) and calculate overall performance measures. Definitions of all coded and derived features during the NA process are also provided in Diewald, Noth [124], whilst calculated performance metrics compared in this study are described below.

5.2.4 Performance Measures

Measures were calculated to describe performance of elite street skaters in competition and were selected to encompass a range of World Skate judging criteria: repetition, difficulty and variety of tricks (obstacle selection, trick selection, originality and innovation), use of course and feature obstacles (number of tricks, variety of obstacles, connecting in line), and run flow/consistency [53]. Quality of execution/landing, style, fluidity, power, aggression, and speed were not directly quantified in this study. Performance measures were grouped by attempt type (RUN, BT) and division (M, W) to explore any differences between the formats and sex. Execution metrics, not 'quality of execution' as per World Skate judging criteria, provided an overview of landed TAs compared to attempted TAs and associated scoring. All other trick and obstacle metrics include both landed and bailed TAs (all attempts). Execution was quantified in two ways: 1) number of landed and bailed TAs and 2) judge-awarded attempt scores.

'Trick selection', encompassing difficulty and variety, was quantified on whether a TA includes a flip, grind, and/or slide, whether it is a 'combination' of multiple tricks, and if so, whether the combination involves a flip into or out of the IA phase. 'Unique tricks' was calculated by counting the number of different TA trick names, across stances (e.g., kickflip and switch kickflip would both be classified under the same unique trick; kickflip). Although TAs performed in different stances are unique in the sense that difficulty levels likely vary [16], we assumed this would be captured by other metrics, such as take-off ($stance_{TO}$) and landing stance ($stance_{LD}$), to avoid any additional collinearity. To this effect, counts and proportions of TAs by $stance_{TO}$ (regular, fakie, nollie, OR switch) and $stance_{LD}$ (regular OR fakie/switch) were calculated. Further derived $stance_{TO}$ features captured which foot popped the board ($stance_{TO-DOM}$: dominant=regular OR fakie, non-dominant=switch OR nollie) and the direction in relation to the approaching obstacle ($stance_{TO-DIR}$: front foot=closest to obstacle, back foot=further from obstacle).

Course usage was quantified by the number of different unique obstacles interacted with, the number of unique mirrored obstacles (same obstacles on opposite sides of the course to account for goofy and regular stance riders) interacted with, and by obstacle types. Usage of feature obstacles includes TAs interacting with the largest course elements (Figure 11). A total of 131 unique obstacles were predefined [124], with 100% course usage indicating interaction with all 131 obstacles. Notably, this predefined list of obstacles is based on specific definitions used in our analysis, though interpretations of what constitutes an obstacle would likely vary between individuals or contexts.

Prior to statistical analysis, redirection tricks were removed: acid drops (M=1 TA, W=1 TA) and kick-turns (M=24, W=22)). Unless otherwise noted, potential other redirection tricks such as coping tricks (e.g., Backside (BS) 50-50 stalls) were included [124].

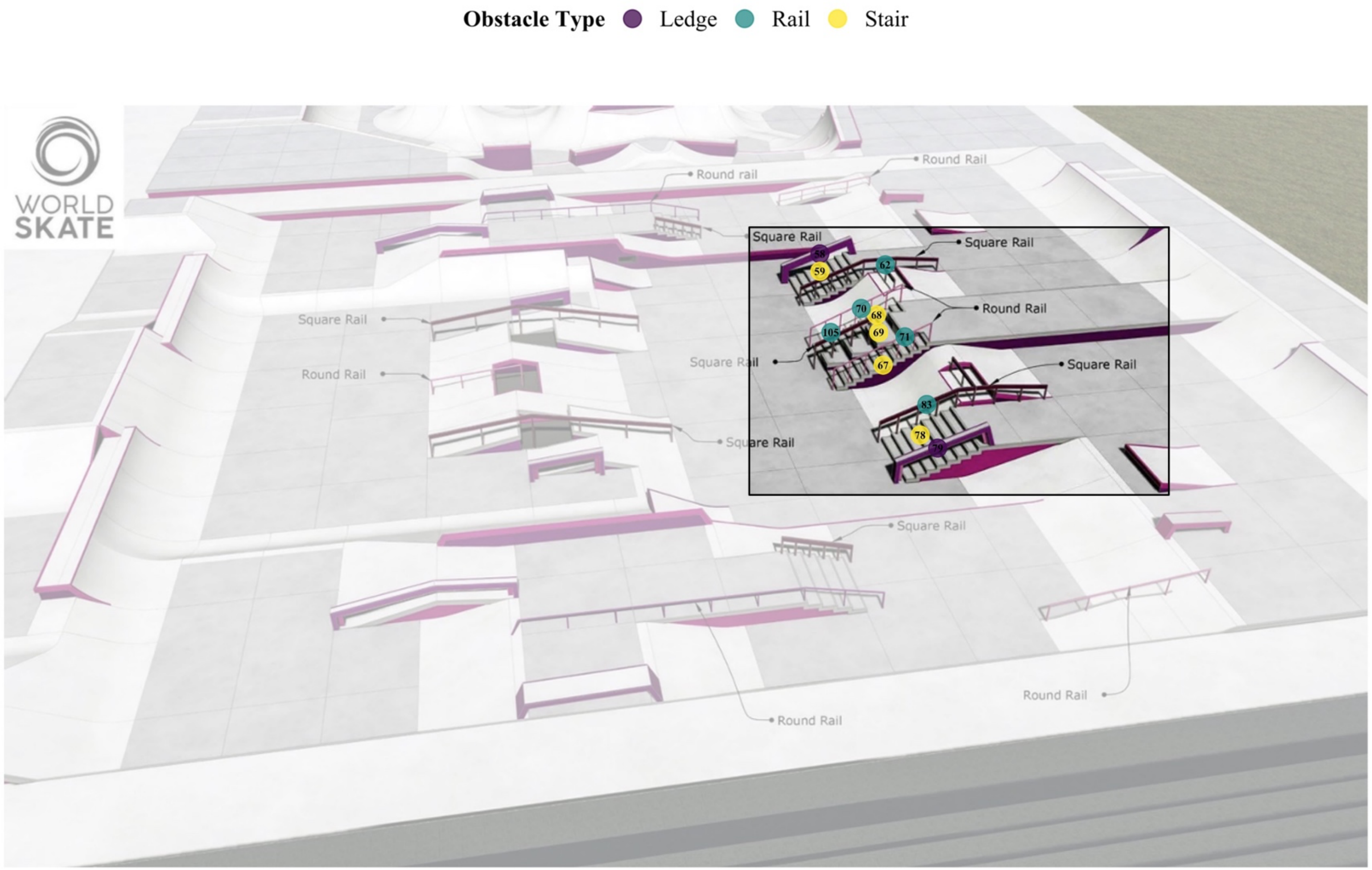


Figure 11: Feature obstacles at the Ariake Urban Sports Skatepark, including ledges (#79-#58), rails (#83-#62, #71-#70, #105), and stairs (#78-#59, #67-#68, #69). Underlying image was accessed and modified from https://www.skateboarding.worldskate.org/news/1478-tokyo-2020-course-designs.html.

5.2.5 Statistical Analyses

Statistical analysis was performed using R, and the following primary packages: *tidyverse* for data wrangling [102], *lme4* (lmer) [125] and *robustlmm* (rlmer) for modelling [126], *performance* package for assessing model fits and assumptions [127], and *moments* for distributional characteristics [128].

To address the aim of determining whether scores differed by division, we applied several linear mixed-effect models (LMM). These were deemed preferable given the multiple observations (attempts) for skaters. Separate models were fit for RUN (Model 1) and BT attempts (Model 2), each with division as a fixed effect and skater ID as a random intercept. All bailed BT TAs (n=153) were removed before fitting LMMs. Prior to interpreting model outputs, assumptions were assessed using various approaches (e.g., Q-Q and other residual plots to ensure approximate residual normality and heteroscedasticity, via 'check_model()' from the *performance* package). In multiple cases, violations of normality were observed, primarily due to outliers. In lieu of removal, we adopted robust models (i.e., rlmm), which typically exhibited better fit and decreased error (judged via marginal R^2 and RMSE, respectively). From each model, standardised coefficients and 95% confidence intervals (CI), raw unstandardised coefficients and 95% non-parametric CIs using 1000 bootstrapped samples. Marginal R^2 and conditional R^2 were presented as indices of model fit, and to describe the proportion of variance explained by division and skater, respectively. The alpha level for all tests was set at a=0.05.

Exploratory frequency analysis (mean ± standard deviation [SD]) was used to describe and compare what happens in Olympic competitions, with semi-finals and finals combined for all analyses. Performance measures are presented as overall counts (TAs, skaters) and percentages of groups (division and attempt type [RUN, BT]). Various measures describing the distribution of attempt scores were performed, including centrality (mean, median), spread (SD, interquartile range [IQR]), skewness, and kurtosis [with associated kernel density plots and quantile-quantile plots]).

5.3 Results

After removing 48 redirection TAs, 1118 TAs (M=602, W=516) remained; including 838 RUN TAs (M=462, W=376) and 280 BT TAs (M=W=140).

5.3.1 Scores

Distribution characteristics of attempt scores are displayed in Figure 12, with model summaries in Table 19. Fixed effect of division explained up to 91.9% of the variation in score. Overall, BT attempts (5.43±3.01) were scored higher than RUN attempts (4.39±2.74). On average, males scored 4.23 points higher in RUN attempts (M=6.59±2.07, W=2.19±1.02) and 5.37 points higher in BT attempts (M=8.22±1.33, W=2.85±1.37). Median scores followed a similar pattern, with men achieving higher medians (BT=8.65, RUN=7.12) than women (BT=2.95, RUN=2.22). Men's scores were more variable in RUN attempts as indicated by a higher SD (male=2.07, female=1.02) and IQR (male=2.39, female=1.70). Women's scores were more variable in BT attempts (SD: M=1.33, W=1.37, IQR: M=1.06, W=2.34). Men's score distributions were left skewed and peaked, particularly for BT attempts (-2.33 skewness, 9.74 kurtosis), and RUN attempts (-1.18 skewness, 3.67 kurtosis). In contract, distributions for the women were roughly normal in BT (-0.06 skewness, 1.95 kurtosis) and RUN (0.04 skewness, 2.17 kurtosis) attempts.

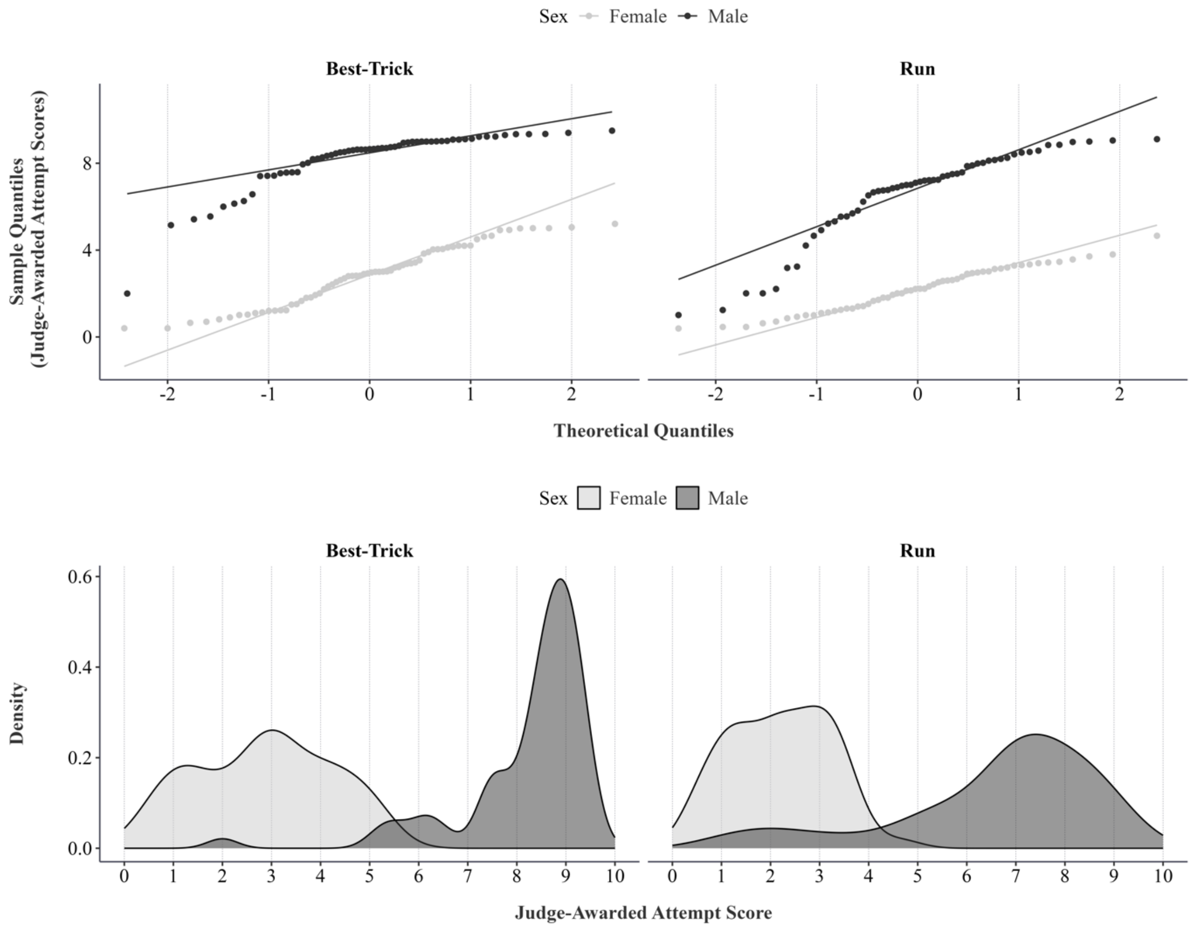


Figure 12: Distribution characteristics of judge-awarded attempt scores for best-trick and run attempts by division. The top panel displays quantile-quantile plots comparing the sample quantiles of score to theoretical normal quantiles for men and women. Note: Bailed best-trick attempts were removed and thus the density plot presented does not reflect the 153 bails that resulted in a score of 0.

Table 19: Run and best-trick robust linear mixed-effects model fit statistics for judge-awarded attempt scores from the men's and women's street skateboarding Olympic debut

	Judge-Awarded Attempt Scores	
	Model 1: RUN Attempts	**Model 2:** BT Attempts[b]
(Intercept)	**2.07 [1.86, 2.32]**[a]	**2.55 [2.32, 2.88]**[a]
Standardised Coefficient (β)	-0.85 [-1.04, -0.65]	-0.96 [-1.16, -0.75]
Division (Men)	**4.69 [4.19, 5.10]**[a]	**5.57 [5.14, 5.92]**[a]
Standardised Coefficient (β)	1.71 [1.43, 1.99]	1.85 [1.55, 2.15]
Number of Attempts	112	127
Number of Skaters	40	38
Var: Skater (Intercept)	1.12	1.33
Var: Residual	0.715	0.55
Conditional R^2	0.93	0.969
Marginal R^2	0.758	0.919
ICC	0.711	0.853
RMSE	0.913	0.63

BT best-trick; *RUN* run; *CI* confidence interval;

This table reports the unstandardised and standardised (β) fit statistics for judge-awarded attempt scores from RUN and BT attempts.

[a] Non-parametric 95% CIs were calculated using bootstrapping (1000 samples)
[b] All bailed BT attempts (where score was zero) were removed prior to fitting the models.

5.3.2 Performance Measures

5.3.2.1 Overall Summary

A summary of trick selection performance measures are provided in Table 20. Of all TAs, 24.4% (273) were bailed; of which 58.6% (160) occurred during LD, 35.2% (96) during obstacle IA phase, and 6.2% (17) at TO. Skaters attempted 159 (14.2%) unique tricks (excluding obstacle details), resulting in 27 different trick types (https://osf.io/n9bjy/). Excluding obstacle details, skaters attempted 116 unique tricks in RUN TAs (13.8%) and 90 unique tricks in BT TAs (32.1%).

TAs were attempted and landed in all stances. All 40 competitors popped tricks in regular stance (RUN=40, BT=32 skaters), 15 in fakie (RUN=13, BT=9 skaters), 12 in switch (RUN=11, BT=6 skaters), and 11 in nollie (RUN=8, BT=5 skaters). Only three skaters (all men) attempted a trick in every stance. Most TAs (83.1%) were landed in regular stance (85.8% RUN TAs, 75% BT TAs), compared to fakie/switch (16.7%) (14.2% RUN TAs, 24.3% BT TAs). Overall, slides represented the greatest proportion of TAs, followed by grinds and flips. Combination tricks made up a larger proportion of BT TAs (54.6%) compared to RUN TAs (21.0%); 62.6% of which were flipped into and/or out.

Table 20: Overall frequency analysis of trick selection performance measures from the men's and women's street skateboarding Olympic debut

	Number of TAs (% of Overall)		
Total TAs	**Overall 1118**	**RUN Attempts 838**	**BT Attempts 280**
Grind Trick	336 (30.1%)	230 (27.4%)	106 (37.9%)
Slide Trick	450 (40.3%)	299 (35.7%)	151 (53.9%)
Flip Trick	353 (31.6%)	225 (26.8%)	128 (45.7%)
Flip In/Out Trick[a]	206 (18.4%)	97 (11.6%)	109 (38.9%)
Combination Trick	329 (29.4%)	176 (21.0%)	153 (54.6%)

TA trick attempt; *BT* best-trick; *RUN* run;

This table reports percentages if total trick attempts by trick selection performance measures, encompassing difficulty and variety, from all RUN and BT attempts. Encompasses both semi-finals and finals round TAs. Trick selection performance measures are not mutually exclusive.

[a] Flip In/Out Trick=specific variation of a combination trick where skater flips their board into and/or out of another trick, usually a grind or slide.

Skaters interacted with 105 out of the 131 obstacles (80.2%); including 100% of ledges, 87.5% of rails (14/16), and 71.4% of stairs (5/7). During RUN attempts, skaters interacted with the same proportion of ledges (100%) and rails (87.5%), but only 3 of the 7 possible stair sets (42.9%). During BT attempts, skaters interacted with a smaller proportion of the course; 50% of ledges, 62.5% of rails, and 57.1% of stairs. Featured obstacles were used in a greater portion of BT TAs (84.3%, 236) compared to RUN TAs (22.0%, 654). A detailed summary of performance measures is presented in Table 21.

Table 21: Division and attempt type frequency analysis of trick selection and execution performance measures from the men's and women's street skateboarding Olympic debut

	Number of TAs (% of Overall)			
	RUN Attempts		**BT Attempts**	
	Women's	**Men's**	**Women's**	**Men's**
Execution				
Total TAs[b]	**376**	**462**	**140**	**140**
Landed	307 (81.6%)	411 (89.0%)	66 (47.1%)	61 (43.6%)
Bailed	69 (18.4%)	51 (11.0%)	74 (52.9%)	79 (56.4%)
Trick Selection[c]				
Unique Tricks	60 (16.0%)	90 (19.5%)	38 (27.1%)	61 (43.6%)
Grind Trick	137 (36.4%)	93 (20.1%)	67 (47.9%)	39 (27.9%)
Slide Trick	102 (27.1)	197 (42.6%)	60 (42.9%)	91 (65.0%)
Flip Trick	70 (18.6%)	155 (33.5%)	41 (29.3%)	87 (62.1%)
Flip In/Out Trick	9 (2.4%)	88 (19.0%)	30 (21.4%)	79 (56.4%)
Combination Trick	16 (4.3%)	160 (34.6%)	38 (27.1%)	115 (82.1%)
$Stance_{TO}$[b]				
Regular	364 (96.8%)	363 (78.6%)	135 (96.4%)	69 (49.3%)
Fakie	6 (1.6%)	33 (7.1%)	5 (3.6%)	25 (17.9%)
Nollie	3 (0.8%)	33 (7.1%)	0 (0.0%)	26 (18.6%)
Switch	3 (0.8%)	33 (7.1%)	0 (0.0%)	19 (13.6%)
$Stance_{TO\text{-}DIR}$[b]				
Back	367 (97.6%)	396 (85.7%)	135 (96.4%)	89 (63.6%)
Front	9 (2.4%)	66 (14.3%)	5 (3.6%)	51 (36.4%)
$Stance_{TO\text{-}DOM}$[b]				
Dominant	370 (98.4%)	396 (85.7%)	140 (100%)	95 (67.9%)
Non-Dominant	6 (1.6%)	66 (14.3%)	0 (0.0%)	45 (32.1%)
$Stance_{LD}$[b]				
Regular	352 (93.6%)	367 (79.4%)	132 (94.3%)	78 (55.7%)
Fakie/Switch	24 (6.4%)	95 (20.6%)	8 (5.7%)	60 (42.9%)
Undetermined	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (1.4%)
Use of Course and Feature Obstacles				
Feature[a] IA Obstacle	74 (19.7%)	110 (23.8%)	101 (72.1%)	135 (96.4%)

TA trick attempt; *BT* best-trick; *RUN* run; *IA* event/interaction; *TO* take-off; *LD* landing; *DIR* direction; *DOM* dominance;

Measures were defined using World Skate judging criteria [11] (execution, use of course and featured obstacles, and difficulty and variety of tricks). Values are presented as overall counts of TAs and proportions of overall counts (% of TAs) within each respective descriptive measure. Performance measures are grouped by division and attempt type, RUN or BT. Encompasses both semi-finals and finals round TAs.

[a] Feature obstacles were the largest obstacles in the skate park and included gaps, stairs, rails, and ledges (total of 12 different obstacles and 7 unique obstacles when accounting for mirroring)
[b] Each measure *is* mutually exclusive, and TAs can only fall under one category
[c] Each measure *is not* mutually exclusive, and TAs can fall under multiple categories

Overall, the most attempted tricks were the Kickflip (62 TAs, 10 M, 17 W) [129] and Frontside (FS) Boardslide (37 TAs, 1 M, 13 W) [130]. The trick the most men attempted was the 360 Flip (32 TAs, 10 M, 2 W). Women attempted the BS Boardslide (34 TAs, 2 M, 14 W) [131] and FS Boardslide [130] the most. In addition, the most attempted combination trick was the 'BS Bigspin + FS Boardslide' (25 TAs, 7 M, 2 W) [132]. Comparatively, there were 11 tricks that three or more women attempted (e.g., eight women attempted the BS Boardslide).

5.3.2.2 Execution

Combining RUN and BT TAs, men bailed less (21.6%, 130 TAs) than the women (27.7%, 143 TAs), however landed a smaller proportion of their BT TAs (Table 21). TA execution was higher during RUNs (14.3% bailed) than BTs (54.6% bailed). More TAs were bailed during the LD phase of RUN TAs (70%) than IA (25.0%) and TO (5.0%) phases. BT TAs were also bailed most during LD (49.7%) and IA (43.1%) phases.

5.3.2.3 Trick Selection

One in every 4.92 TAs by the men were unique (112 unique TAs). One in every 6.97 TA by the women were unique, encompassing 74 unique tricks. The men attempted a greater proportion of unique tricks than women in BT TAs (M=1 in 2.30, W=1 in 3.68 TAs) and RUN TAs (M=1 in 5.13, W=1 in 6.27 TAs).

Men attempted 19 different trick types, 17 in RUNs and 11 in BTs. Women also attempted 19 trick types, 14 in RUNs and 13 in BTs. TAs in the men's division were slides (47.8%), flips (40.2%), and grinds (21.9%). Overall, TAs in the women's division mostly encompassed grinds (39.5%), slides (31.4%), and flips (21.5%). Only 10.5% of the women's TAs were combination tricks, attempted by 12 skaters. A full breakdown by trick type is available in the online material (https://osf.io/n9bjy/).

All 20 men attempted a combination trick, representing 45.7% of all TAs. Moreover, 27.7% of the men's TAs were flipped into or out of the obstacle interaction phase (by 18 men), compared to 7.6% of the women's TAs (by 8 women). Figure 13 and Figure 14 show all men's and women's TAs by trick name.

TAs were popped in all stances: $stance_{TO}$=regular (71.8% males, 96.7% females), fakie (9.6% males, 2.1% females), nollie (9.8% males, 0.6% females), and switch (8.6% males, 0.6% females) (1 male TA was undetermined) (Table 22). Compared to 17 male skaters, only seven female skaters popped their board in a stance other than regular. Only one female skater (11 male skaters) attempted a switch trick, and two female skaters (nine male skaters) attempted a nollie trick.

Men popped off their front foot more in BT TAs (36.4%) and their back foot in RUN TAs (85.7%). Women popped off their back foot in 97.3% (502) of TAs (M=80.6%, 485). Females only popped off the front foot in 14 TAs (2.7%) (5 BT TAs, 9 RUN TAs). Men popped off their board with their non-dominant foot in 18.4% (111) of TAs and more during BTs (32.1%, 45) than RUNs (14.3%, 66). Conversely, women used their non-dominant foot in 1.2% (6) of TAs, all occurring in RUNs.

Table 22: Take-off stance breakdown of trick attempts from the men's and women's street skateboarding Olympic debut

		Number of Skaters (% of Division)			
	Stance$_{TO}$	**Regular**	**Fakie**	**Nollie**	**Switch**
	Stance$_{TO\text{-}DIR}$	Back	Front	Front	Back
	Stance$_{TO\text{-}DOM}$	Dominant	Dominant	Non-Dominant	Non-Dominant
All TAs	**Women**	20 (100%)	5 (25%)	2 (10%)	1 (5%)
	Men	20 (100%)	10 (50%)	9 (45%)	11 (55%)
RUN TAs	**Women**	20 (100%)	3 (15%)	2 (10%)	1 (5%)
	Men	20 (100%)	10 (50%)	6 (30%)	10 (50%)
BT TAs	**Women**	20 (100%)	2 (10%)	0	0
	Men	12 (60%)	7 (35%)	5 (25%)	6 (30%)

TA trick attempt; *BT* best-trick; *RUN* run; *TO* take-off; *DIR* direction; *DOM* dominance;

This tables reports the number of men and women skaters whom attempted TAs un various take-off stances, grouped by foot dominance and direction. Percentages represent the proportion out of the 20 skaters in each division, respectively. Encompasses both semi-finals and finals round TAs.

Including bails, most TAs were attempted to be landed in regular stance (73.9% M, 93.8% W) as opposed to fakie/switch (25.7% M, 6.2% W). Compared to all but one man (95%), eleven women (55%) attempted to land TAs in fakie/switch.

Regarding specific unique tricks (exclusive of stance), in RUN attempts, skaters in the women's division attempted the Kickflip the most (32 TAs, 9 skaters), followed by the FS Boardslide (30 TAs, 13 skaters). More than 11% of all men's RUN TAs were 360 Flips (27 TAs, 10 skaters) [133] or Kickflips (26 TAs, 8 skaters). Also, men and women attempted 15 unique tricks, respectively, in RUNs only once. In total, 48 unique tricks were attempted in men's RUNs by only a single skater, compared to 33 unique tricks attempted by a single skater in the women's division.

In men's BT attempts, no more than 3 skaters attempted the same trick; Full Caballerial (Cab) + BS Lipslide [134]; the only occurrence. There were 50 unique tricks attempted by only a single skate in the men's division. Only 9 of the 61 BT unique tricks attempted by men were also attempted by a skater in the women's division. During the women's BT attempts, the BS Crooked Grind [135] was attempted most by 5 different skaters (11 TAs), although the BS Boardslide was attempted by 8 different skaters in 8 TAs. The second most attempted women's BT trick was the Kickflip + BS Boardslide [136] (9 TAs), by 3 skaters. A full breakdown of RUN and BT TA counts and trick names for the men's and women's are provided in Figure 13 and Figure 14.

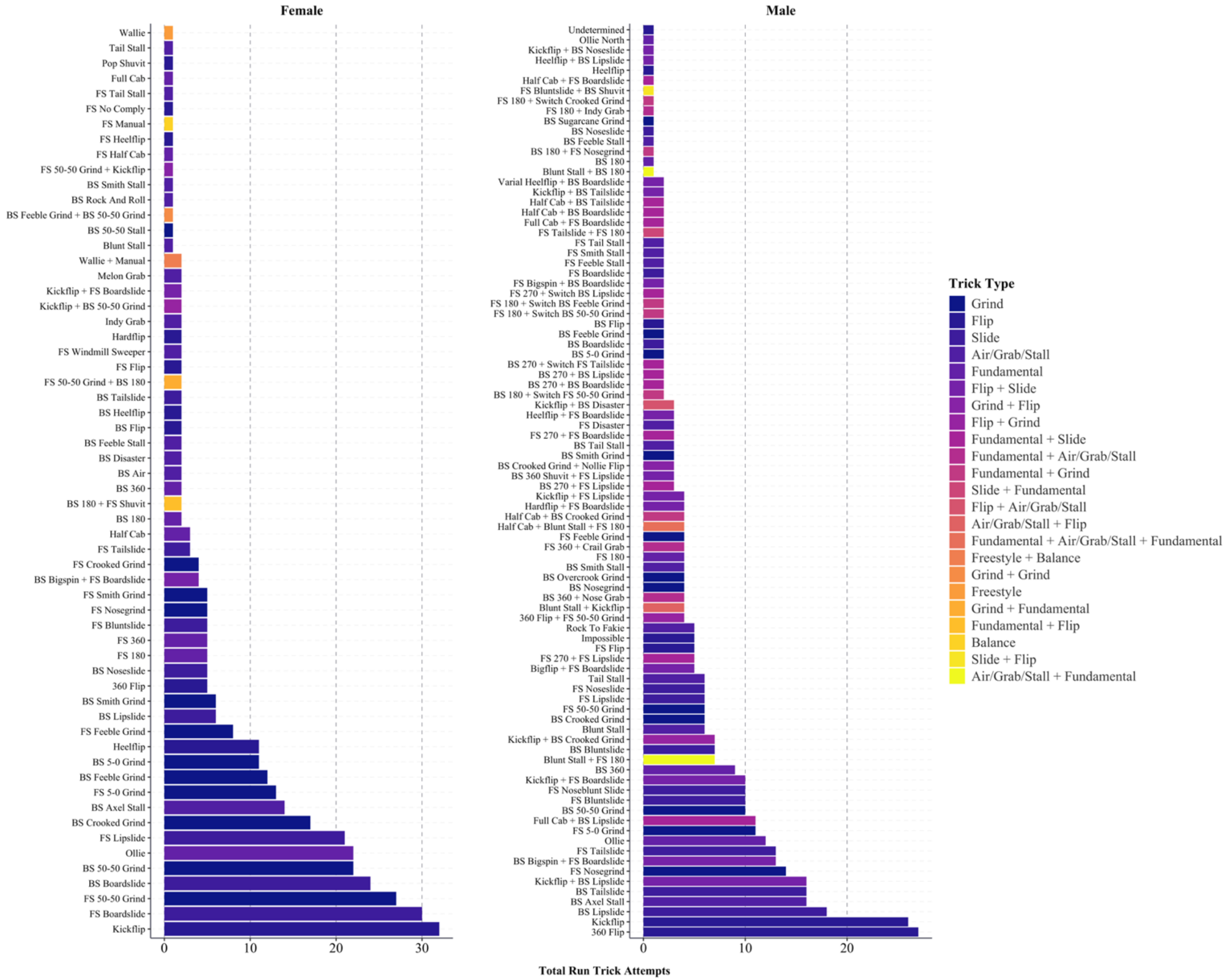


Figure 13: Distribution of *run* trick attempts (both landed and bailed) in the men's and women's division at the Tokyo 2020 Olympics (semi-finals and finals rounds combined).

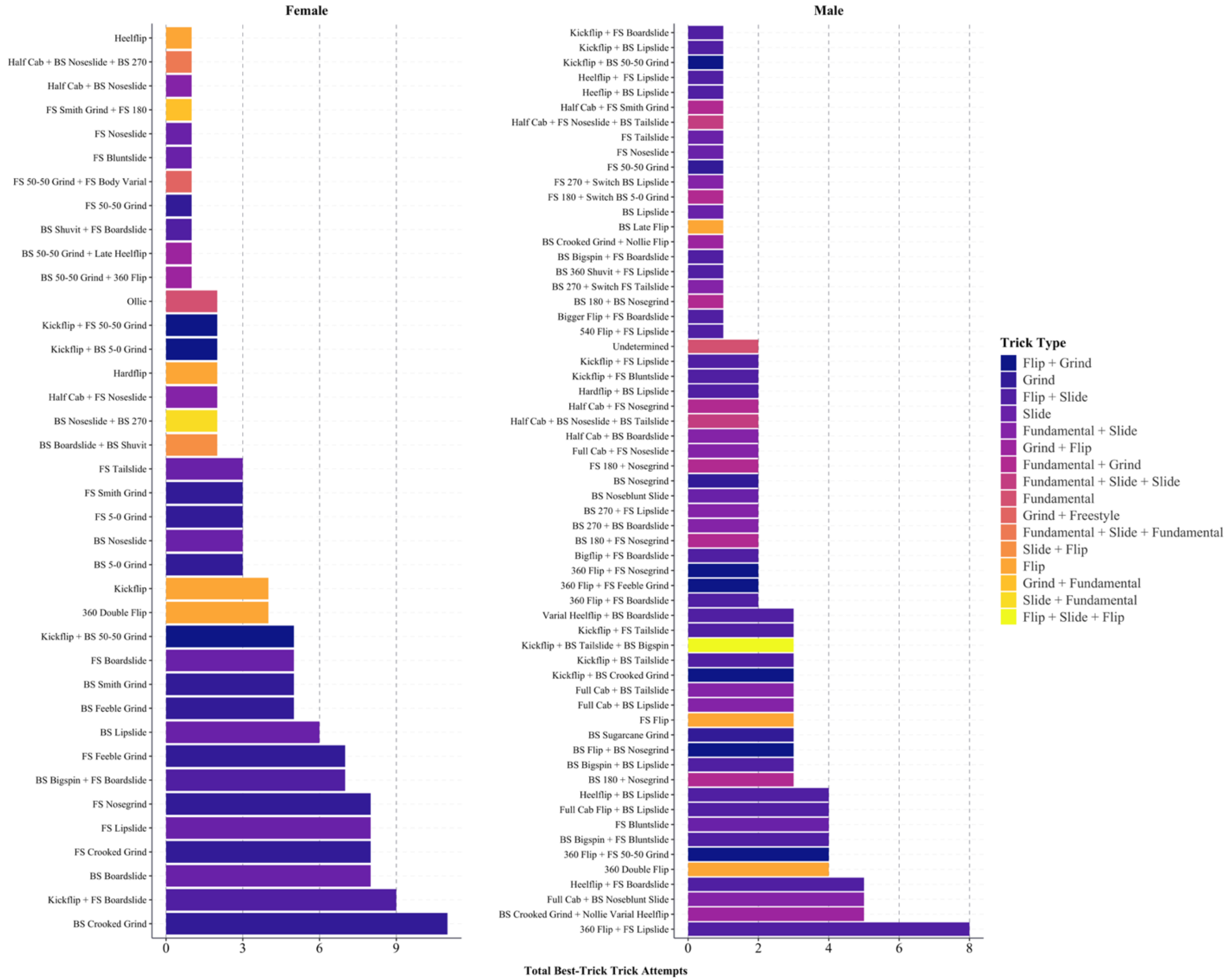


Figure 14: Distribution of *best-trick* trick attempts (both landed and bailed) in the men's and women's division at the Tokyo 2020 Olympics (semi-finals and finals rounds combined).

5.3.2.4 Use of Course and Feature Obstacles

Men and women interacted with 73.3% (96) and 69.5% (91) of the 131 labelled obstacles in the skatepark. Specifically with regards to obstacle type, women utilised between 70-75% of ledges (9/12), rails (12/16), and stair sets (5/7). Men utilised more than 80% of rails (14/16) and ledges (10/12), but only 1 of the 7 stair sets.

During BT TAs, men used 16.0% (21/131) of the labelled obstacles, compared to 32.1% by women (42/131). During RUN BTs, men used 72.5% (95/131) of labelled obstacles, compared to women (67.2%, 88/131). Men interacted with a feature obstacle 40.7% of all TAs, slightly more than the women (33.9% of all TAs). Both skaters in the men's and women's divisions utilised feature obstacles in greater proportion during BTs than RUNs, overall.

When accounting for mirrored obstacles, the most used obstacle during the IA phase varied by division. Among the men's division, the most used obstacles were square rails in RUNs ('#83-#62' featured square rails – 49 TAs, 10.6%) and BTs (#105 featured square rail – 58 TAs, 41.4%); all of which are feature obstacles (Figure 11), apart from '#47-#40' round rails; long flat followed down the 5-stair. Among the women's division, round rails were the most interacted with in RUNs ('#47-#40' round rails – 45 TAs, 12%) and BTs ('#71-#70' featured round rails – 30 TAs, 21.4%).

5.4 Discussion

The aim of this study was to explore aspects of performance in Olympic street skateboarding competitions during the 2020 Tokyo Games. RUN and BT scores were higher and descriptively more variable in the men's compared to the women's division, with the latter tending to bail more frequently. Skaters in the men's division demonstrated varied trick selection; skaters in the women's division displayed mostly regular stance grind tricks, notably in RUNs.

Although men's and women's scores in the analysed Olympic competition were presumably judged on the same scale, performance measures varied between divisions. There was a statistically significant difference between the men's and women's scores, with men scoring 4.7 points higher during RUN, and 5.6 points higher during BT attempts. Men's RUN scores were more variable compared to women's, whereas the opposite was true for BTs (men's BT scores were less variable). This might suggest a broader perceived range of skill in the women's BT TAs compared to men's, highlighted by the greater IQR and supported by the degree of trick repetition within this format. One possible explanation for this might be attributable to the relative newness of skateboarding as a sport for women. Alternatively, it is possible that even if there was a broader range of skill in the men's division, the skaters have identified better scoring strategies within this competition format, potentially from greater experience in this competition format.

The "2/5/4" format of competition used at the Olympics was designed such that skaters attempted their most difficult (riskiest), highest scoring potential tricks in the BT section; the greater number of allowed BT attempts hints bails are expected. Moreover, skaters were more consistent during RUNs, whilst bailing almost a quarter of BT TAs. RUN format highlights skaters' ability to link stylish tricks together, aesthetically flowing through the skatepark. Accordingly, more and greater trick variety, through changing board and skater movement, were observed during BT attempts, however less obstacle variability was found when compared to RUNs. This likely reflects the relative ramification of bailing in a BT (automatic zero) versus RUN attempt; this harsher penalty in the BT section heightens the risk, forcing skaters to balance potential high scores against total point loss. Insights into what trick characteristics relate to better scores would enable athletes and coaches to assess the relative risk of more difficult attempts.

The greater variability and higher scoring in men's RUNs likely stems from more diverse take-off/landing stances, more trick types (e.g., combination tricks), and broader use of the course's large, feature obstacles. In contrast, women's wider BT variability coincided with greater course coverage but less reliance on feature obstacles, possibly reflecting lower speeds from a younger and probably less experienced cohort (3 years younger, on average). The men attempted presumably more technically demanding tricks, which likely relied on greater height and speed, whilst the women tended to bail proportionally more, despite fewer women's RUN TAs than men's. These patterns suggest that differences in trick selection, encompassing variety and difficulty, reflect a combination of physical and technical factors, which may be shaped by experience and maturity rather than inherent skill gaps. As this format of competitive skateboarding gains traction, these distinctions may evolve, offering a chance to reassess how such factors influence performance in future competitions. Moreover, if the risk-reward relationship of BT and RUN attempts is to be understood, more analysis is needed.

Although a few skaters in the women's division varied their stance and attempted combination tricks, the women showed greater performance spread, likely driving higher trick repetition. One possible explanation is the more recent uptake of female skateboarders in the community [137]. To that effect, it was hypothesised that judges may place greater emphasis on novelty only once certain criteria have been met, such as utilising feature obstacles or performing combination tricks. For example, a skater in the women's division executing a 'simpler' trick on a larger obstacle might be rewarded more heavily for its uniqueness relative to her competitors. In contrast, a skater in the men's division may have relied on alternative strategies, such as varied take-off and landing stances and trick types to distinguish themselves. So, despite competing on the same course and presumably judged on the same criteria, men's and women's street skateboarding are likely better viewed as separate, individual competitions, whereby performances and strategies may be reflected uniquely within scoring. Consequently, judges' preferences, relative weighting of criteria, and resulting outcomes should be explored independently of division and format.

To provide an overall picture of competitive performance to effectively determine training priorities, tactical strategies and resulting competition level outcomes (final round scores and rank) could also be explored. However, scoring has changed since the Olympic debut of skateboarding [97]. The men's and women's divisions are no longer judged on the same scale [13]; scoring is relative to that specific round-division (e.g., men's semi-finals). Therefore, if comparisons between division of future competitions is of interest, methods of standardising scores should be implemented.

5.4.1 Limitations, Practical Applications, and Future Research Direction

Olympic street skateboarding is in its infancy, requiring fast adapting training techniques to keep up with varying levels of performance and changing competition formats and judging modalities. One limitation within this study is the evolving structure of competitions, as demonstrated by the Paris Qualifiers and subsequent Olympics [13]. These changes in format and scoring may influence performance measures and competition outcomes. A standardised approach as described above would help alleviate these challenges. Additionally, this study only captures a select number of quantifiable performance criteria at the group level. Skater-level metrics, such as the number of tricks per RUN, or whether a skater landed their first and last trick of a RUN, would add more context to understanding competitive skateboarding performance. Also of note, quality of execution metrics, such as style, were not captured, despite their likely importance to success [108]. Tactical strategies, such as when to try the most difficult trick, are also likely related to Olympic exposure and a skater's ability to perform under pressure. These factors are difficult to quantify and outside of scope. Lastly, the performance measures used in this study were mostly reduced to either describe trick or obstacle factors, independently. Consequently, trick difficulty could not be directly assessed. Future research should look to implement a more ecologically valid approach by aligning with judging practices and exploring metrics that integrate trick and obstacle details together to better reflect the overall performance of each TA. This would be facilitated by the aggregation of future competitions to explore if findings are relevant over time.

5.5 Conclusion

Street skateboarding debuted at the Tokyo Olympic Games and the men's and women's divisions were judged on the same scoring scale, presenting an opportune moment to explore and compare performances. There were key differences in performance and scoring between the divisions, with men typically scoring higher. As the sport evolves, there is a clear need for PA approaches that allow practitioners to implement standardised methods of comparing attempt and overall scores. More to that effect, how these differences are reflected in judge preferences and overall competition outcome; and accordingly, what coaches and athletes should prioritise in training remains unclear across both cohorts.

CHAPTER 6:

SEND IT? PERFORMANCE INDICATORS OF THE TOKYO 2020 OLYMPIC STREET SKATEBOARDING HIGHLIGHT THE IMPORTANCE OF BALANCING RISK FOR COMPETITIVE SUCCESS

This chapter comprises the following paper *in preparation for submission* to the *European Journal of Sports Sciences:*

Diewald, S. N., Mancini, N., Thorp, S., Neville, J., Cronin, J. B., & Cross, M. R. (2025). Send it? Performance Indicators of the Tokyo 2020 Olympic Street Skateboarding Highlight the Importance of Balancing Risk for Competitive Success. *European Journal of Sports Sciences*, *In preparation for submission.*

Prelude:

Building on the descriptive findings from Chapter 5, it was evident that men's and women's street skateboarding differed not only in score, but also in performance characteristics. Specifically, the men appeared to differentiate themselves by varying aspects of their tricks including stance, trick selection (human and board movements), and course use. Although skaters in the women's division utilised a wider selection of obstacles during the BT section, the men used more of the skatepark during the RUN section; possibly through the greater number of tricks that were attempted. In result, a greater level of trick repeatability (less uniqueness) was seen in the women's division across the competition, and thus differentiation between skaters likely originate from other performance factors. These differences suggest that both division (sex) and attempt type influence how athletes approach performance and potentially how performances are judged. Chapter 5 described performance differences, however it is still unclear how these differences relate to overall judging preferences, and thus, competition outcomes. Specifically, it is critical to understand if elements that distinguish success in RUN attempts are the same as those in BT attempts. Along similar lines, reasons underpinning the significant difference in men's and women's scoring, and how judging patterns and the relative contribution of different performance criteria to successful outcomes reflect the nuances of each respective division. To explore these questions, the aim of Chapter 6 was to examine determinants of successful performances in BT and RUN attempts from the women's and men's Tokyo 2020 Olympic Games. Using the knowledge accrued over the preceding chapters, Chapter 6 used statistical and systematic approaches to select objective performance metrics that could explain variation in overall impression scores awarded by judges.

CHAPTER 6: SEND IT? SUCCESSFUL STREET SKATEBOARDING STRATEGIES DURING THE 2020 TOKYO OLYMPICS

6.1 Introduction

Street skateboarding is a discipline that focuses on performing tricks in urban environments and is the form most commonly associated with the term 'skateboarding' [138]. Competitive street skateboarding has grown in popularity, becoming an Olympic sport at the Tokyo 2020 Games [2]. Where key performance indicators (KPIs) are well-defined in other action-based sports [32, 139], what drives performance in skateboarding remains unclear [98]. Accordingly, improving the ability to understand and measure aspects of performance associated with success in competitive street skateboarding is increasingly important, potentially benefiting a wide range of stakeholders including athletes, coaches, judges, media and fans.

Within the semi-final and final rounds of the Tokyo Olympics, skaters attempted five single best-trick (BT) trick attempts (TA), and 2x45 second runs (RUN). Following each attempt, a panel of judges awarded an overall impression score (0.00-10.00 points) guided by World Skate judging criteria; trick variety and difficulty, use of course and 'feature', larger obstacles (i.e., urban-inspired elements like stairs, rails, ledges, that mimic real-world street environments), repetition, run flow and consistency, and execution [11]. However, the aggregation of criteria into a single impression score makes decomposing performance into its determinants difficult [139]. For example, a given score could comprise various combinations of aspects underlying the aforementioned criteria, or perhaps one aspect is more important than another. This ambiguity was recently echoed by four male Olympians who each reported a different criteria as 'most important' for competition success [108]. To effectively prepare for competition, coaches and skaters require clarity on how judges allocate criteria when ranking BT and RUN performances, respectively.

Performance analysis is a common technique to describe and quantify sports performance, including that of board sports [140, 141]. Specific application in skateboarding has seen notational analysis (NA) applied to TAs and their phases (take-off (TO), obstacle interaction (IA), landing (LD)) to describe the technical demands of the women's and men's divisions, respectively [142]. Whilst women demonstrated variety in obstacle selection in the BT section, this coincided with less frequent use of larger, feature obstacles. Men showcased greater trick variety through flip tricks, varying TO stances, and combination tricks; however, it remains unclear what specifically differentiated individual performances and how awarded attempt scores were determined. Although men's and women's scores differed significantly (β=1.71-1.85), how these differences reflected overall competition outcomes remains uncertain. Clarifying these relationships would provide valuable insights for skaters to prepare for the specific demands of their respective division.

The aim of this study was to examine determinants of successful performances in BT and RUN attempts from the women's and men's Tokyo 2020 Olympic street skateboarding competition. To this end, quantitative performance metrics based on World Skate judging criteria were used to explain and compare variation in judges' scores and provide coaches and athletes with objective indicators of success in elite street skateboarding.

6.2 Methods

6.2.1 Experimental Approach to the Problem

In this cross-sectional study, a custom NA method was applied [124] to quantify performance aspects of the men's and women's street skateboarding competition and subsequently identify KPIs of RUN and BT attempts with regards to judges' overall impression scores. The NA method and associated underlying dataset are described in detail elsewhere [124] and summarised below.

6.2.2 Dataset

Forty (20 M, 20 W) street skaters competed in the 2020 Tokyo Olympics semi-finals, eight of which, respectively, progressed to the finals. Publicly available, high-quality (~1080p, 60 frames per second) broadcast video footage (https://olympics.com/, access date: 05 March 2022) of 280 BT (M=W=140 TAs) and 112 RUN (M=W=56) attempts across semi-final and final rounds, resulting in 1118 individual TAs [142]. No specific ethical approval was sought from any university board due to the public nature of the dataset.

6.2.3 Model Variable Engineering, Selection, and Outlier Analysis

For each skater and attempt, TAs were classified and measures of performance were extracted using the aforementioned NA software. All BT and RUN variables were calculated within each attempt and skater, making them specific to the round (semi-finals, finals). In this sense, the number of attempts varied by skater. Prior to modelling, the measures were reviewed and screened for errors and outliers, leveraging descriptive statistics and visualisations. Subsequently, two attempts were removed from the men's dataset. Both attempts were considered 'throw-away' TAs, after the skaters had already been eliminated from qualification for the next round of competition. Specifically, only one BT attempt was scored below 5.00 points (score=2.00, FS 50-50 Grind) [143], and thus, was not deemed representative of the sample. Additionally, of all men's BT TAs, only one attempt did not occur on a feature obstacle (score=6.14, FS Flip [gap]) [144], and the outlier was removed prior to modelling.

Variables were calculated and selected to represent aspects of performance based on judging criteria using a combination of expert knowledge, previous literature, and practical constraints. These were compiled within a conceptual framework informed by existing skateboarding research and findings from similar judged board sports, like surfing [145] and snowboarding

[34, 139]. Notably, the relatively small sample size limited the number of variables that could be included in the models whilst achieving reasonable statistical power.

BT and RUN variables tested for model inclusion are described in Table 23. Notably, all RUN variables capture only landed TAs unless otherwise specified (TA_{TOTAL}, TA_{BAIL}). All BT ($Time_{TA}$, $Time_{IA}$) and RUN ($Avg\text{-}Time_{TA}$) time variables, and RUN percentage variables (% Unique Obstacles, % Feature Tricks, % Non-Regular $Stance_{TO}$, % Combination Tricks) were mean-centred, but categorical variables and RUN count variables (TA_{TOTAL}, TA_{BAIL}) were not. If all division TAs were associated with a single level of a variable (W: $Stance_{TO\text{-}DOM}$='Dominant', M: Feature Trick=TRUE), the variable was not included in the model and is represented accordingly (–).

Table 23: Best-trick and run model variable descriptions

	Variable Name (Reference Value, if applicable)[b]	Definition
BT Attempt Variables	**[a]Stance$_{TO\text{-}DOM}$** (REF: Dominant Foot)	Whether the TO pop was by the dominant or non-dominant foot (defined by the skaters' preferred stance)
	[a]Stance$_{TO\text{-}DIR}$ (REF: Back Foot)	Whether the TO pop was by the front or back foot (in relation to direction of movement towards the obstacle)
	Stance$_{LD}$ (REF: Regular)	Stance at landing (regular, fakie/switch)
	Time$_{TA}$	Time from board pop to landing
	Time$_{IA}$	Time on obstacle: air-time (for aerial tricks), grind/slide/stall time, manual time, etc.
	[a]Obst-Type$_{IA\text{-}MOD}$ (REF: Other)	Whether Obst-Desc$_{IA}$ was a square rail, round rail, or other (any ledge, gap, stair, bank, etc.) *(Modified from Obst-Type$_{IA}$ and Obst-Desc$_{IA}$)*
	Feature Trick (REF: FALSE)	TRUE if TA interacted with one of pre-determined 'feature' (larger) obstacles on course
	Combination Trick (REF: FALSE)	TRUE if skater combined more than 1 trick through flipping or rotating (>180 degrees) (body and/or board) into and/or out of grind, slide, air/grab/stall, balance, or freestyle trick-type$_{IA}$.
	Flip Trick (REF: FALSE)	Whether skater flipped board in any direction during TA
	Trick-Type$_{IA\text{-}MOD}$ (REF: Grind)	Whether Trick-Type$_{IA}$ was a grind, slide, or other
RUN Attempt Variables	**Avg-Time$_{TA}$**	Mean Time$_{TA}$ of all non-transition TAs
	TA$_{TOTAL}$	Total number of TA (land or bail), including all transition tricks
	TA$_{BAIL}$	Total number of trick bailed, including all transition tricks
	% Unique Obstacles	Proportion of unique obstacles interacted with during IA phase across all landed TAs
	% Feature Tricks	Proportion of feature obstacles interacted with during IA phase across all landed TAs
	% Non-Regular Stance$_{TO}$	Proportion of TAs popped in fakie, switch, or nollie across all landed TAs
	% Combination Tricks	Proportion of 'Combination Trick' TAs across all landed TAs
	% Flip Tricks	Proportion of 'Flip Trick' TAs across all landed TAs
	% Unique Trick-Type	Proportion of unique Trick-Type$_{TA}$ across all landed TAs

BT best-trick; *TA* trick attempt; *TO* take-off; *IA* interaction; *LD* landing; *MOD* modified; *DOM* dominance; *DIR* direction;

[a] TA variables were modified from description provided in Diewald, Noth [124] notational analysis methods
[b] Reference values for categorical and Boolean variables, selected as the most commonly occurring (and presumably least difficult)

Table 24: Best-trick and run model variable associated World Skate judging criteria [11]

	Variable Name (Reference Value, if applicable)[b]	**Repetition**	**Difficulty & Variety of Tricks**	Obstacle Selection	Trick Selection	Originality and Innovation	**Quality of Execution / Landing**	**Use of Course & Feature Obstacles**	Number of Tricks	Variety of Obstacles	Connecting Tricks in Line	**Run Flow and Consistency**
BT Attempt Variables	[a]**Stance$_{TO-DOM}$** (REF: Dominant Foot)		**X**		X							
	[a]**Stance$_{TO-DIR}$** (REF: Back Foot)		**X**		X							
	Stance$_{LD}$ (REF: Regular)		**X**		X							
	Time$_{TA}$		**X**	X	X		**X**					
	Time$_{IA}$		**X**	X	X		**X**					
	[a]**Obst-Type$_{IA-MOD}$** (REF: Other)		**X**	X								
	Feature Trick (REF: FALSE)		**X**	X				**X**				
	Combination Trick (REF: FALSE)		**X**		X							
	Flip Trick (REF: FALSE)		**X**		X							
	Trick-Type$_{IA-MOD}$ (REF: Grind)		**X**		X							
RUN Attempt Variables	**Avg-Time$_{TA}$**								X		X	**X**
	TA$_{TOTAL}$								X			**X**
	TA$_{BAIL}$								X		X	**X**
	% Unique Obstacles	**X**				X		**X**		X		
	% Feature Tricks		**X**	X				**X**		X		
	% Non-Regular Stance$_{TO}$		**X**		X							
	% Combination Tricks		**X**		X							
	% Flip Tricks		**X**		X							
	% Unique Trick-Type	**X**	**X**		X	X						

BT best-trick; *TA* trick attempt; *TO* take-off; *IA* interaction; *LD* landing; *MOD* modified; *DOM* dominance; *DIR* direction;

'X'=Judging criteria most likely reflected

[a] TA variables were modified from description provided in Diewald, Noth [124] notational analysis methods
[b] Reference values for categorical and Boolean variables, selected as the most commonly occurring (and presumably least difficult)

6.2.4 Statistical Analyses

Statistical analysis was performed using R and primarily the following packages: *tidyverse* for data wrangling [102], *lmerTest* for modelling [146], and *performance* for assessing linear model fits and assumptions [127].

To address our aim of identifying aspects of successful BT and RUN attempts, linear mixed effects modelling (LMM) was used. Bailed BT TAs (n=153) were excluded prior to model fitting. Four separate models were built for women's (BT, $Model_{BT-W}$; RUN, $Model_{RUN-W}$) and men's attempts (BT, $Model_{BT-M}$; RUN, $Model_{RUN-M}$) to examine the relationship between various performance aspects and scores. To account for multiple attempts per skater, participant ids were included as a random intercept in each model. Competition round was tested as an additional random effect but ultimately excluded due to negligible contribution (e.g., similar or higher AIC, lower R^2), favouring a simpler model structure. Reference values for categorical variables were selected as the most common, and/or presumably least difficult (see Table 23). Model development was guided by Hox's bottom up approach [147], whereby final model inclusion was determined by balancing model fit (e.g., R^2, RSME) and complexity (e.g., AIC, BIC), ensuring both predictive capability and meaningful exploration of performance associations. This included 2nd order terms for variables in RUN attempts to account for non-linear relationships (per a combination of conceptual basis and observing model residuals).

Prior to interpreting model outputs, assumptions were assessed leveraging residuals plots via the *performance* package. In multiple cases, we observed violations of normality which appeared largely attributed to outliers. Subsequently, we tested the robustness of our findings using a machine learning (ML) approach. Specifically, four XGBoost regression models, one per LMM, were trained to predict scores, leveraging its gradient-boosting algorithm for accuracy and resistance to overfitting, with leave-one-out cross-validation to optimise hyperparameters. Shapley Additive exPlanations were used to interpret variable contributions, confirming key predictors [148, 149]. Practical interpretations from each model remained quite stable across LMM and ML approaches, and so we opted to present the LMMs due to their simplicity and interpretability. ML methods and results are available upon request.

For each LMM, we reported raw coefficients and bootstrapped 95% confidence intervals (CI). Overall model fit was assessed using both marginal (R_M^2) and conditional R^2 (R_C^2), representing the variance explained by fixed effects and the combined fixed and random effects, respectively. Attempt-level (R_{L1}^2) and skater-level R^2 (R_{L2}^2) were reported to indicate the proportion of variance explained within attempts and between skaters. Fixed effect estimates were obtained using restricted maximum likelihood estimation, and the statistical significance of individual predictors was assessed using t-tests with Satterthwaite's approximation for degrees of freedom, implemented using the *lmerTest* package. Standardised coefficients were obtained post hoc using the *effectsize* package (standardize_parameters) [150]. The alpha level for all tests was set at $\alpha = 0.05$. Statistical significance and coefficients are reported throughout the manuscript as it pertains to models for women and men using an associated subscript (e.g., p_W and p_M, respectively).

6.3 Results

When accounting for both fixed and random effects, BT and RUN models explained substantial variance in attempt score, with models for RUN scores (R_C^2: W=89.0%), M=96.1%better fit than for BT scores (R_C^2: W=89.5%, M=76.5%).

6.3.1 Best-Tricks

Fixed effects explained 52% and 30.2% R_M^2) of women's and men's BT attempt scores, respectively (Table 25). Only 34.7% (R_{L2}^2) of between male skater variance was explained by *Model$_{BT\text{-}M}$*. In comparison, 71.5% (R_{L2}^2) of between female skater variance was explained by

Model$_{BT\text{-}W}$. Women tended to score higher in BT when they used feature obstacles (β_W=0.86, p_W<0.001), performed flip tricks (β_W=1.10, p_W<0.001), used their forward-facing, dominant foot to pop the board (fakie stance) (Stance$_{TO\text{-}DIR}$, β_W=1.10, p_W=0.002), did grinds compared to slides (Trick-Type$_{IA\text{-}MOD}$:Slide, β_W=-0.24, p_W=0.044) or others (Trick-Type$_{IA\text{-}MOD}$:Other, β_W=-1.14, p_W=0.047), and interacted with a round rail (Obst-Type$_{IA\text{-}MOD}$, β_W=0.40, p_W=0.008) compared to any other obstacle type. Skaters in the men's division tended to score higher if they landed a combination trick (β_M=1.38, p_M=0.001) or interacted with a feature round rail obstacle (Feature Trick, Obst-Type$_{IA\text{-}MOD}$:Round Rail, β_M=0.40, p_M=0.021). Also, although not statistically significant, flip tricks (β_M=1.10, p_M=0.052) and use of a feature square rail obstacle (Feature Trick, Obst-Type$_{IA\text{-}MOD}$: Square Rail, β_M=0.03, p_M=0.077) were positively associated with a higher score in the men's division. However, it is worth noting that in some cases, the bootstrapped confidence intervals slightly conflicted with the p-values, as they shifted from close to zero, to crossing zero (i.e., slightly under our alpha threshold, to not statistically significant) (Men's BT Flip Tricks, Women's BT Trick-Type$_{IA\text{-}MOD}^{b}$: Slide and Other). As such, these results should be interpreted with caution.

Table 25: Summary of linear mixed-effects model analyses of the relationship between aspects of performance judging criteria and best-trick attempt scores from the men's and women's Tokyo Olympics street skateboarding competition.

	Best-Trick Attempts Unstandardised Coefficients [95% CI]			
	Women's *$Model_{BT-W}$*		**Men's** *$Model_{BT-M}$*	
(Intercept)	**1.54 [0.97; 2.04]**	***	**5.15 [3.64; 6.51]**	***
$Stance_{TO-DOM}$[b]: Non-Dominant Foot	–		0.64 [-0.01; 1.28]	
$Stance_{TO-DIR}$[b]: Front Foot	1.50 [0.58; 2.40]	**	0.31 [-0.49; 0.99]	
$Time_{TA}$[a] (s)	0.64 [-1.18; 2.25]		1.42 [-2.74; 4.92]	
$Time_{IA}$[a] (s)	-1.23 [-3.84; 1.35]		-0.96 [-4.76; 2.23]	
Feature Trick: TRUE	1.18 [0.83; 1.56]	***	–	
$Stance_{LD}$[b]: Fakie / Switch	0.18 [-0.35; 0.74]		0.09 [-0.41; 0.56]	
Combination Trick: TRUE	0.03 [-0.64; 0.77]		1.42 [0.63; 2.26]	***
Flip Trick: TRUE	1.51 [0.75; 2.19]	***	0.73 [-0.03; 1.45]	*
$Trick\text{-}Type_{IA-MOD}$[b]: Slide	-0.33 [-0.66; 0.04]	*	-0.52 [-1.11; 0.05]	
$Trick\text{-}Type_{IA-MOD}$[b]: Other	-1.56 [-3.00; 0.13]	*	–	
$Obst\text{-}Type_{IA-MOD}$[b]: Round Rail	0.55 [0.17; 0.96]	**	1.73 [0.47; 3.19]	*
$Obst\text{-}Type_{IA-MOD}$[b]: Square Rail	0.04 [-0.31; 0.46]		1.18 [0.00; 2.46]	
Number of Attempts	66		59	
Number of Skaters	20		18	
Var: Skater (Intercept)	0.54		0.59	
Var: Residual	0.15		0.3	
Conditional R^2	0.895		0.765	
Marginal R^2	0.520		0.302	
Adjusted ICC	0.781		0.663	
RMSE	0.296		0.427	

M men; *W* women; *TA* trick attempt; *TO* take-off; *IA* interaction; *LD* landing; *DOM* dominance; *DIR* direction; *MOD* modified; *s* seconds; *CI* confidence interval;

[a] Mean centred

[b] Categorical variables are relative to a reference value, selected such that they were the most commonly performed (References values: $Stance_{TO-DOM}$=dominant foot, $Stance_{TO-DIR}$=back foot, $Stance_{LD}$=regular stance, $Trick\text{-}Type_{IA-MOD}$=grind, $Obst\text{-}Type_{IA-MOD}$=other

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

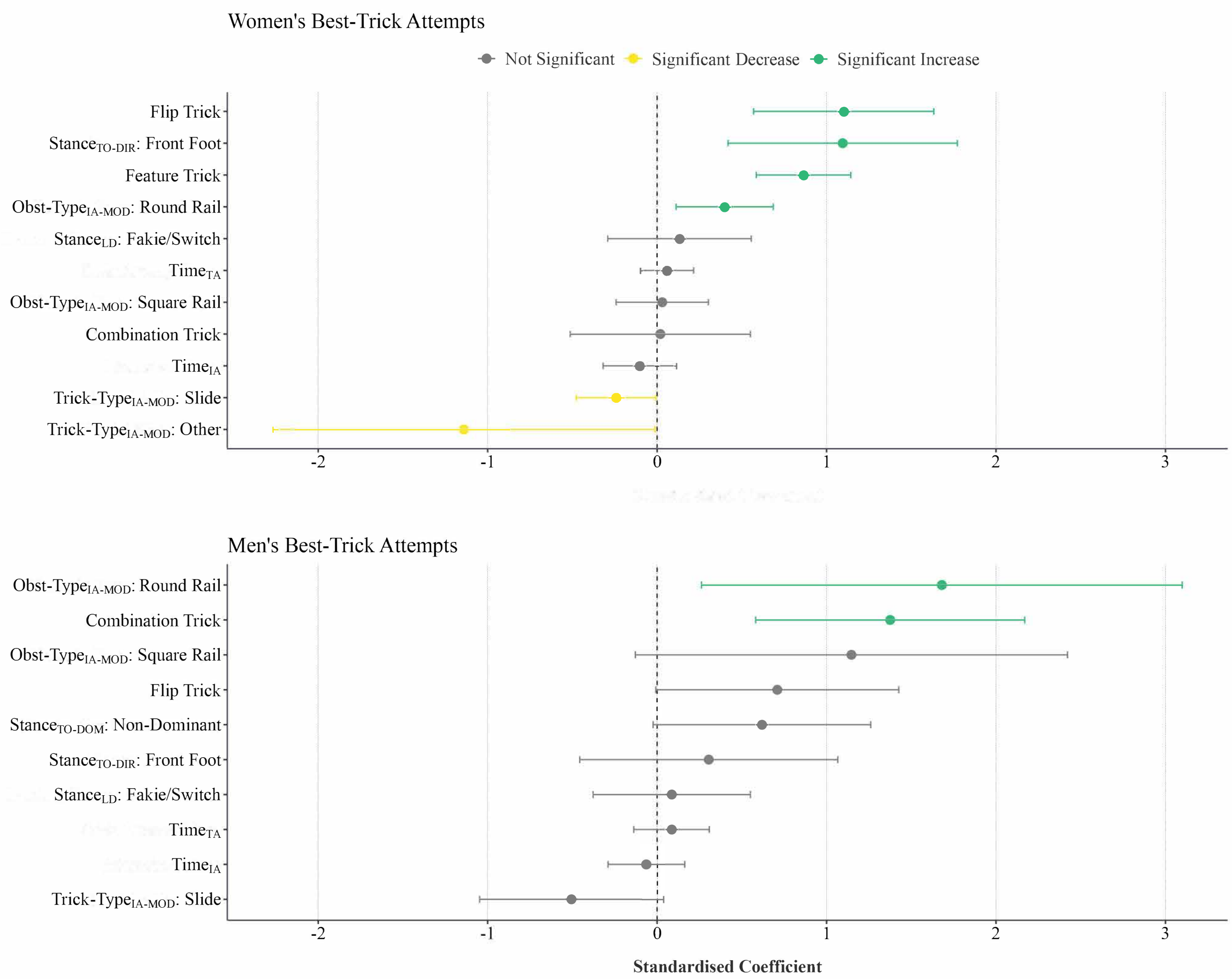


Figure 15: Standardised coefficients for *best-trick* model parameters, depicting the relative influence of each model variable on men's and women's attempt scores, respectively. The error bars represent 95% confidence intervals.

6.3.2 Runs

Fixed effects explained 75.0% and 82.9% (R_M^2) of variance in women's and men's RUN attempt scores, respectively (Table 27). A total of 60% (R_{L2}^2) of between skater variance was explained by $Model_{RUN-W}$. In comparison, 81.2% (R_{L2}^2) of between skater variance was explained by $Model_{BT-M}$.

For both men's and women's division, RUN attempt scores were positively associated with an increased number of total TAs (TA_{TOTAL}, β_W=3.67, p_W<0.001, β_M=4.58, p_M<0.001), however after a certain point, too many TAs were associated with decreased scores, evidenced by significant, negative quadratic terms (TA_{TOTAL}^2, β_W=-2.00, p_W<0.001, β_M=-1.65, p_M<0.001). Also for both disciplines, RUN attempt scores were positively associated with a greater proportion of feature tricks (% Feature Tricks, β_W=0.28, p_W<0.001). In contrast, RUN scores were negatively associated with the number of bailed TAs (TA_{BAIL}, β_W=-0.39, p_W<0.001, β_M=-0.40, p_M<0.001).

Skaters in the women's division who landed a greater proportion of flip tricks (% Flip Tricks, β_W=0.27, p_W=0.009) tended to score higher; whilst skaters in the men's division tended to score higher with a greater proportion of unique trick types (% Unique Trick-Type, β_M=0.23, p_M=0.002). Neither the linear nor quadratic terms for % Combination Tricks and % Non-Regular $Stance_{TO}$ was statistically significant for either discipline.

Table 26: Descriptive summary of *run* attempt variables of performance from the men's and women's Tokyo 2020 Olympics

	RUN Attempts Mean ± SD		
	Overall	**Women's**	**Men's**
# Total Attempts	**112**	**56**	**56**
Avg-Time$_{TA}$[a] (s)	0.803 ± 0.091	0.779 ± 0.105	0.828 ± 0.068
TA$_{TOTAL}$	7.48 ± 1.64	6.71 ± 1.51	8.25 ± 1.39
TA$_{BAIL}$	1.07 ± 0.96	1.23 ± 0.93	0.91 ± 0.96
% Unique Obstacles	95.5 ± 8.8%	96.1 ± 9.5%	94.9 ± 8.2%
% Feature Tricks	17.3 ± 14.3%	16.6 ± 16.7%	18 ± 11.5%
% Non-Regular Stance$_{TO}$	10.8 ± 16.2%	2.6 ± 7.5%	19 ± 18.5%
% Combination Tricks	17.1 ± 17.7%	5.1 ± 10.3%	29.2 ± 15.2%
% Flip Tricks	25.2 ± 22%	17.3 ± 18.5%	33.1 ± 22.5%
% Unique Trick Types	68.5 ± 19.6%	65.5 ± 22.2%	71.6 ± 16.2%

TA trick attempt; *TO* take-off; *Avg* average;

'%' represents the proportion of landed TAs for a specific variable relative to TA$_{TOTAL}$

[a] Excludes all transition TAs

Table 27: Summary of linear mixed-effects model analyses of the relationship between aspects of performance judging criteria and run attempt scores from the men's and women's Tokyo Olympics street skateboarding competition.

	Run Attempts Unstandardised Coefficients [95% CI]			
	Women's *Model*$_{RUN-W}$		**Men's** *Model*$_{RUN-M}$	
(Intercept)	**2.68 [2.38; 2.95]**	***	**7.35 [6.87; 7.88]**	***
Avg-Time$_{TA}$^{ab} (s)	1.06 [-0.44; 2.42]		0.37 [-1.77; 2.36]	
Avg-Time$_{TA}$^{ab} *(s)* *(quadratic)*	-2.10 [-3.47; -0.70]	**	0.22 [-0.98; 1.47]	
TA$_{TOTAL}$	3.73 [2.22; 5.25]	***	9.50 [6.76; 11.86]	***
TA$_{TOTAL}$ *(quadratic)*	-2.03 [-3.13; -1.13]	***	-3.42 [-4.89; -1.74]	***
TA$_{BAIL}$	-0.42 [-0.60; -0.23]	***	-0.87 [-1.28; -0.52]	***
% Unique Obstacles^{b}	-1.16 [-2.63; 0.41]		-2.19 [-5.95; 1.19]	
% Feature Tricks^{b}	1.70 [0.70; 2.60]	***	1.68 [-1.22; 4.53]	
% Non-Regular Stance$_{TO}$^{b}	-1.50 [-3.68; 0.56]		0.69 [-1.28; 2.60]	
% Combination Tricks^{b}	0.42 [-1.73; 2.62]		-0.36 [-3.00; 1.84]	
% Combination Tricks^{b} *(quadratic)*	–		1.44 [-0.28, 3.11]	
% Flip Tricks^{b}	1.46 [0.39; 2.50]	**	0.95 [-0.76; 2.71]	
% Unique Trick Types^{b}	0.09 [-0.96; 1.14]		2.92 [0.98; 4.99]	***
Number of Attempts	56		56	
Number of Skaters	20		20	
Var: Skater (Intercept)	0.14		0.58	
Var: Residual	0.11		0.17	
Conditional R^2	0.890		0.961	
Marginal R^2	0.750		0.829	
Adjusted ICC	0.559		0.770	
RMSE	0.257		0.301	

M men; *W* women; *TA*=trick attempt; *TO* take-off; *IA* interaction; *s* seconds; *CI* confidence interval; *Avg* average; *s* seconds;

'%' represents the proportion of landed TAs for a specific variable relative to TA$_{TOTAL}$.
Where applicable, (quadratic) represents the higher order model variable.
[a] Excludes all coping TAs
[b] Mean-centred
*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$

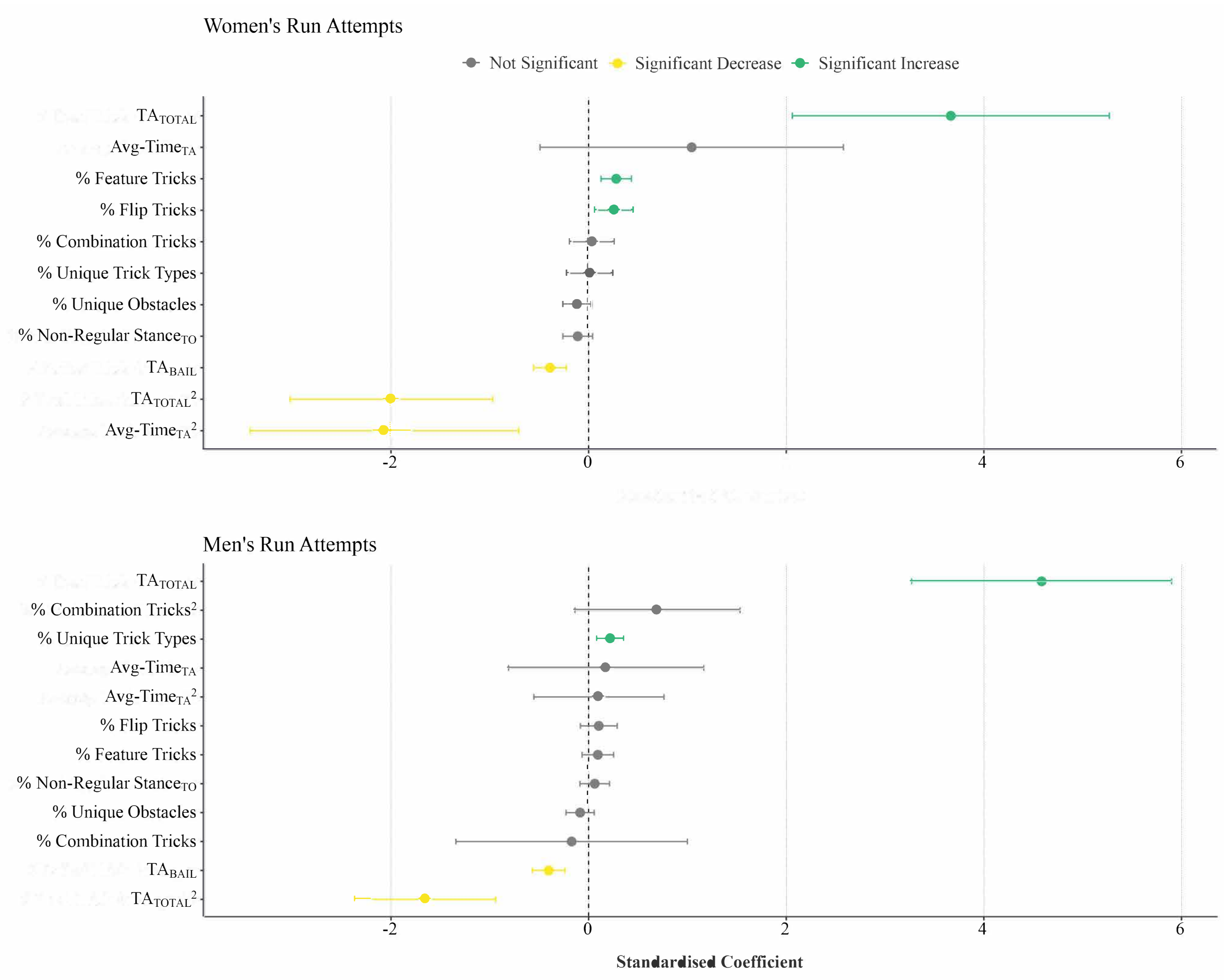


Figure 16: Standardised coefficients for *run* model parameters, depicting the relative influence of each model variable on men's and women's attempt scores, respectively. The error bars represent 95% confidence intervals.

6.4 Discussion

In this study we aimed to identify determinants of successful street skateboarding BT and RUN attempts. Whilst predictors differed between divisions, utilising larger, feature obstacles tended to be associated with higher BT and RUN scores. Where attempting more tricks in a RUN increased score, bailing reduced it. Moreover, after a certain point, more TAs was not associated with a higher score, suggesting diminishing returns. Overall, RUN scores were better explained in the models, particularly for men. Women's BT scores were more predictable than men's, but the unexplained variance in the models likely indicate unmeasured factors, potentially reflecting the relatively noisy and subjective elements of judging performance in the sport.

Broadly, using larger, feature obstacles (as opposed to not) was essential for high scoring BT attempts in both the men's and women's divisions, significantly related to score in both models. When exploring the data descriptively, all landed BT attempts on feature obstacles in the women's division scored higher than landed tricks on any other obstacle, regardless of the trick itself. All BT attempts in the men's division interacted with feature obstacles as well, potentially signifying a hierarchy in importance to overall score. Moreover, BT TAs interacting with round rails scored higher than TAs interacting with square rails or other obstacle types, such as ledges, stairs, or gaps.

Including a greater proportion of feature tricks in RUN attempts was significant for the women, but not the men. Rather, the greatest determinant of RUN score in the men's division was the number of TAs and bails. Scores tended to increase with the number of TAs (in the absence of bails) but diminished after around 8-9 attempts – beyond this peak, additional TAs were associated with lower scores, potentially reflecting a trade-off between quantity and quality, where more difficult tricks reduce overall quantity due to time constraints and fatigue. The type of transition between tricks (e.g., coping, fundamental kick turns or stalls vs. technical transition tricks) may also influence judges' scoring but was not explicitly accounted for in this analysis. Whilst this may be partially reflected in the number of tricks performed in a RUN, transition trick quality and quantity remain an underexplored factor that could contribute to overall impression scores. Unsurprisingly, all other variables held constant, as bailed TAs in a RUN increased, score decreased. Each additional bail in a RUN reduced scores from 14-17% on average (0.4-0.9 points lost per bail, depending on division). So, although adding more TAs into a RUN could be a strategy to improve score, the quality and the risk of bailing should be weighed when deciding which trick to add [151].

Beyond utilising feature obstacles in BT attempts and attaining a reasonable number of TAs and limiting bails in RUNs, determinants of performance diverged. Specifically, BT scores in the women's division were significantly higher when the board was flipped as opposed to not, increasing scores by 53% (vs. 14% in the men's division). This was also evident in women's RUN attempts, where an increased proportion of flip tricks was related with a higher score. A positive, linear relationship was also found for women who popped their BT TAs with their front, dominant foot (fakie stance, as no skater in the division attempted a nollie). However, an increase in non-regular stance TAs during RUNs was not significantly related to score, with the point estimate of the coefficient trending in the opposite direction. In addition to increased trick variety, arguably flipping the board and taking off in different stances are both means by which to increase the technical difficulty of a trick. These findings suggest that flipping the board could be a promising strategy to increase score in the women's division. Nevertheless, varying stance may be preferred for single, higher-risk tricks, like during the BT section. Consideration should be given as to whether it would be worth risking a bail within a RUN. Also, although no skater attempted a BT using their non-dominant foot in the women's division, a positive, more influential trend with score was shown for the men compared to a front foot pop. As such, skaters in the women's division that could utilise their non-dominant foot may have an advantage during BT attempts.

During BT attempts, in addition to feature and round rail obstacle use, a combination trick was found to be related to an increased score in the men's division, resulting in 1.42 more points on average than a non-combination trick. Nevertheless, although combination BT TAs resulted in greater average scores than non-combination BTs for the women, this was not a statistically significant factor in the model. Along similar lines, a greater proportion of combination tricks during RUN attempts did not clearly impact score for either division. Rather, a greater proportion of unique trick types was associated with an increased men's RUN score. Although the statistical approach used, by nature, considers each metric to have a separate and controllable contribution to score (i.e., adjusting for each other factor in the model), it is likely that performance represents a combination of factors which are difficult to isolate. Combination tricks are as described, an amalgamation of two and or more tricks; like a Kickflip + BS Crooked Grind. The ability to combine tricks increases a skater's repertoire substantially and allows them to perform uniquely. Similarly, the proportion of unique trick types was not a statistically significant predictor of women's RUN scores, suggesting that beyond performance differences between divisions, judges may apply distinct evaluative criteria emphasizing obstacle type and variety in the women's division, yet trick type and variety in the men's. These findings suggest that skaters in the men's division may particularly benefit from increasing their 'bag of tricks' to choose from during RUNs, and combining tricks together may be an optimal strategy to do so during BT attempts.

In our analyses we opted to remove bailed BT TAs, which encompassed 54.6% of the data for the associated models. On the one hand, the reduced data yield for these analyses could have reduced the ability to delineate meaningful relationships from noise. On the other hand, judging criteria such as repeatability, obstacle variety, and trick variety suggests a skater's previous attempts (bailed or landed) likely influence the scoring of the next attempt. More to this effect, the order of attempts undoubtedly influences decision-making, as skaters adjust their strategy based on previous success or failure. For example, if a trick has already been landed by another competitor, this would likely influence judges' scores and thus may influence an athlete's tactics. The fit of our models aligns with this theory, with RUNs (including bailed and landed TAs) being more predictable than BTs. Low R^2 values from both BT models further supports the notion that there are other factors not included in the model contributing towards score, such as the performance of bailed and landed previous BT attempts, that should be explored in future analyses.

The differences in marginal and conditional R^2 values of our BT models (52.0% $Model_{BT\text{-}W}$, 30.2% $Model_{BT\text{-}M}$) also indicates nearly half the variance in scores could be attributed to within-skater factors, more so for men, which were less predictable overall. Few women were able to land combination tricks on feature obstacles [142], leading to dominant scores by a few high performers. Whilst other factors captured in the model could discriminate women's performances, such as take-off stance, within skater factors like individual style, may play a larger role in discriminating the performance of BTs in the men's division. A recent survey of competitive skaters supports this theory, with style reported as the most important factor related to performance in both competitive and recreational settings, albeit lacking elite female representation [108]. The inclusion of quantifiable personal style factors (e.g., rotations into and out of tricks, rotation direction, specific tricks, etc.) in future models may better describe performance differences between men. As the sport continues to evolve and interest and performance in the women's division likely increase, KPIs may change. Conducting a similar analysis on more recent competitions would illuminate whether the findings in this competition are valid and transferrable.

Although the linear relationship between Avg-Time$_{TA}$ and women's RUN scores was not statistically significant, a non-linear pattern emerged, potentially suggesting diminishing returns beyond a certain point. Additionally, no other time metric (Avg-Time$_{TA}$, Time$_{TA}$, Time$_{IA}$) significantly impacted BT scores in either division, or men's RUN scores. Whilst there are many possible explanations for this finding, all remain speculative. Time is likely an incomplete proxy for other influential factors, such as speed [11], that could not be directly measured or included in the models. Moreover, the unclear relationship is unsurprising given the variety of interacting variables likely at play; for example, longer trick durations may reflect differences in trick type, obstacle length and complexity, or execution quality, which were only partially accounted for in the model.

6.4.1 Limitations, Practical Applications, and Future Research Direction

One of the primary, though expected, limitations in this study was the small sample size. Ultimately, we were constrained by the number of TAs during the competition, which likely limited the ability to detect effects and eventually include other performance-related factors (such as a hierarchical structure of round) into our models. Future research should make use of larger sample sizes (e.g., longitudinal data through more competitions) to include additional within and between skater factors related to prior performances to support tactical decision making. Along similar lines, the exclusion of bails from the BT analysis impacted our ability to capture risk-taking behaviour and subsequent impacts on score, a critical element of street skateboarding competitions, which should also be explored in future studies. Moreover, we acknowledge that not all aspects of performance are quantifiable. In this study, we purposefully chose quantifiable and modifiable aspects of competitive performance to provide skaters and coaches actionable insights by which competition tactics could be strategically explored.

Our statistical approach, linear hierarchical modelling, was chosen for simplicity whilst remaining ecologically valid and capturing nuances of the sport (repeat attempts, within-skater variation, etc.). However, limitations of this approach should not be ignored. In addition to the exclusion of factors, no interactions between variables were included in the model. Although this reductionist view of tricks and obstacles is easily interpretable, future research should implement strategies to model trick and obstacle interactions to accurately represent judging criteria and performance, almost certainly leveraging increasingly available datasets.

Albeit limited in sample size and findings yet to be substantiated across other competitions and formats, this research provides key insights for practitioners and athletes looking to compete in street skateboarding on the world stage:

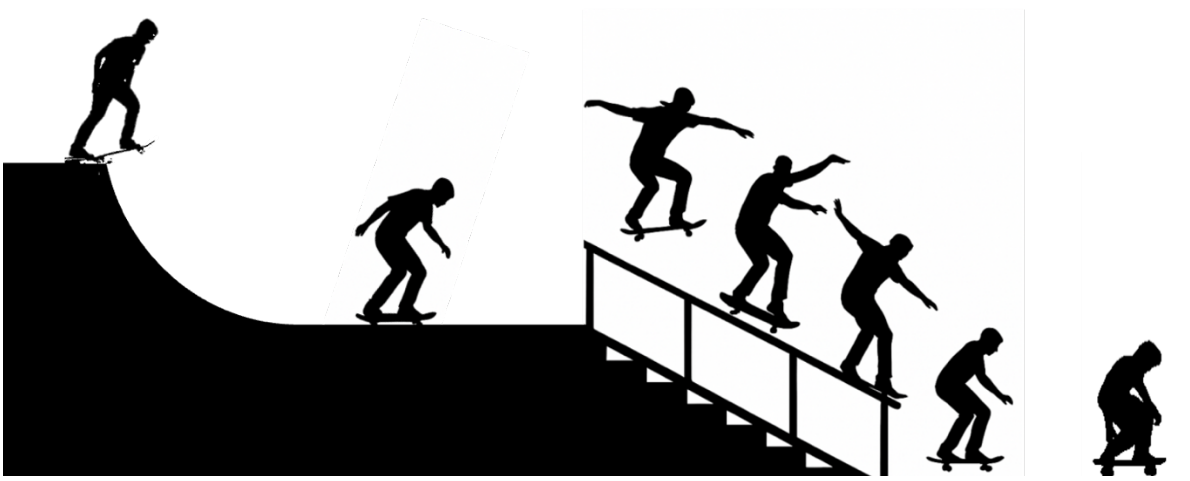
- Using feature obstacles is critical to achieving high scores in the BT and RUN sections
- More tricks attempts (to a certain point) and less bails are key contributors to RUN scores, but performance analysis should be used to explore the risk-reward implications when planning RUNs and BTs (send it?)
- Skaters competing in the women's division can distinguish themselves in BTs by using larger obstacles, flipping the board, and varying take-off stance, however the risk of bailing should be weighed when looking to implement these technically difficult elements into RUNs.
- Skaters in the men's division should leverage their individual novelty and style, particularly during BT attempts, by looking to increase their bag of tricks to choose from, with combination tricks a probable strategy.

6.5 Conclusion

Competitive street skateboarding is a subjectively judged, freestyle sport with competition formats designed to capture creativity of human and board movement within an urban-like environment, whilst being able to rank performances as better or worse. Skaters who utilise feature obstacles, whilst balancing the risk of attempting more and varied tricks with the impact of bailing, will likely be more successful in competition. What discriminates competitive performance in the men's and women's division should continue to be explored to best support skaters as the sport and its athletes evolve.

SECTION 4: 'LAND BOLTS'

TRANSLATING FINDINGS INTO PRACTICE



CHAPTER 7:

A PICTURE OF COMPETITIVE STREET SKATEBOARDING PERFORMANCE

Prelude:

The preceding chapters provide a comprehensive picture of our current understanding of competitive street skateboarding performance, from the scoping of current knowledge and community perceptions to the development of reliable measurement frameworks and their application in elite-level analysis. Chapter 2 of this thesis highlighted a critical gap in our understanding of competitive skateboarding performance; limited research, methodological inconsistency, and a lack of objective data left the landscape largely unmapped. In response, the intervening chapters sought to build clarity, generating new insights through community engagement, framework development, and performance analysis (PA) of elite-level competition. In doing so, Chapter 7 shifts from exploration to application, providing coaches, analysts, and skaters with a practical model to support training, preparation, and performance in the lead-up to future Olympic Games. Chapter 7 draws these threads together to reflect on the journey undertaken throughout the thesis, highlighting key findings and their practical implications for skaters, coaches, and performance staff. In doing so, it revisits the central question posed at the outset of this work: *what constitutes a successful performance in competitive skateboarding?* Ultimately, this chapter aims to serve both as a reflection on progress and a springboard for further innovation in understanding and supporting success in Olympic skateboarding.

CHAPTER 7: PRACTICAL APPLICATIONS: A PICTURE OF COMPETITIVE STREET SKATEBOARDING PERFORMANCE

7.1 A Guide to Understanding and Measuring Street Skateboarding

The aim of this chapter is to provide coaches and practitioners with practical insights into competitive street skateboarding performance, supported by a model to guide training, preparation, and performance in the lead-up to future Olympic Games. Street skateboarding disciplines debuted at the Olympics in Tokyo 2020 [48]. What was once fully subjective at the outset, this thesis showcased the use of objective elements to quantify aspects of performance providing insights into judging decisions. This guide translates key findings from each chapter of the thesis to practice, and where possible offers recommendations for performance planning and monitoring in a rapidly developing sport. Notably, competitive skateboarding is steadily evolving, so to ensure utility, this guide places findings into context, and highlights what exactly this means for practice now, with the future of Los Angeles 2028 in mind. Practically, this section presents the findings from the thesis, separated by chapters, and elaborates on how this can be translated to actionable insights for coaches, skaters, and researchers.

7.2 Chapter 2 Findings

Whilst Chapter 2 highlighted a gap of understanding of what technical and tactical elements underscore performance, it did provide some insights into potentially important physical characteristics. Although physical attributes have yet to be directly linked to competitive performance outcomes, findings from the scoping review suggest that underlying physical demands likely provide a physiological basis upon which technical proficiency and tactical decision-making can be built. Physical preparation could include the following areas:

7.2.1 Aerobic Capacity to Enhance Training Volume Tolerance, Recovery Between Attempts, and Consistency Across Rounds

A **foundational aerobic capacity** likely supports skaters' training volume tolerance, recovery between attempts, and performance longevity. Street skaters demand repeated high-intensity efforts, often within time-limited runs. Whilst no direct evidence quantifies aerobic demands in skateboarding, researchers from analogous action sports (e.g., snowboarding, surfing) have suggested a sufficient aerobic base may facilitate performance consistency across multiple rounds [36].

7.2.2 Lower-Body Strength, Power, and Range of Motion to Support Trick Execution, Speed Generation, and Injury Resilience

Lower-limb strength and power are also likely integral to competitive skateboarding. Notably, explosive power could aid movements such as the pop during ollies, generating sufficient height to execute tricks [21]. Whilst lower-limb strength could likely support skaters to manage the demands of switch stance tricks and to use larger obstacles effectively, the necessary balance at low versus high movement speeds remains unclear. However increased capacity in these areas is unlikely to be detrimental in the worst of cases. Being able to express strength over quite broad ranges of the lower-limbs is probably advantageous to landing mechanics, and might mitigate a degree of injury risk [75]. Nonetheless, whilst minimum physical thresholds for competitive success probably exist, they have yet to be defined.

7.2.3 Neuromuscular Control to Optimise Landing Mechanics

Neuromuscular control likely underpins a skater's ability to execute technical skills with precision and adapt dynamically to the environment [152]. Evidence suggests that balance, proprioception, and motor control could support trick execution and injury prevention. Flexibility in the knees, ankles, and hips allows quicker lower-limb repositioning during aerial manoeuvres and safe landings [22, 46]. Repetitive, high-impact landings [24] highlight the need for strong neuromuscular strategies to dampen loads and avoid injury, yet these capacities remain under-investigated in elite skaters.

7.3 Chapter 3 Findings

7.3.1 Prioritise Style

Coaches and skaters should prioritise style, particularly by including trainable elements of clutch and flow states [107] in preparation for competition. Moreover, style is underpinned by both subjective and objective elements, of which aspects of the latter can be reliably obtained from broadcast video footage (Chapter 4) and could be used to monitor progress and accordingly guide training.

7.3.2 Implement Discipline- and Skill-Specific Training Approaches

Researchers and practitioners should implement PA methodologies that capture the distinct characteristics and unique competitive requirements of street and park skateboarding. For example, from the survey it was found that street skaters should prioritise originality and variety. Therefore, PA techniques should prioritise these elements. Moreover, perceptions of success differed by skill level, and as such, practitioners should consider this when preparing for various competitions.

7.3.3 Acknowledge Differences Between World Skate Judging Criteria and Skater Priorities

Researchers, practitioners, and skaters should recognise the distinct performance demands of competitive skateboarding compared to recreational skateboarding. It would seem that the number of tricks within a run may not be important to competitive or recreational success as reported by community skaters. However, if competitive success is a priority, skaters and coaches must acknowledge the importance of the trick count, evidenced by World Skate judging criteria, and latter thesis findings (Chapter 6). When preparing runs for competition, skaters and coaches should be clear on judge expectations and adjust their RUN and BT strategies accordingly.

7.4 Chapter 4 Findings

7.4.1 Leverage NA for Competition and Training, Balancing Detail with Time Available

By applying a scalable and consistent data collection framework, coaches can balance the depth of insights with practical constraints, maximising the value of both basic scoring data and more advanced notational analysis when resources allow. Once data are consistently captured, a range of analytical approaches can be applied to extract insights and track progression.

7.4.2 Leverage Broadcast Footage for Training

Where available in 'high-quality' form, broadcast footage can be used to reliably capture skateboarding-specific measures related to performance. Specifically, spatio-temporal features can serve as proxies for objective aspects of style. Nonetheless, pending the quality of the footage, missing data could be an issue. Accordingly, practitioners should look to adopt methods of dealing with this in their analysis, where relevant.

7.4.3 Consider Technological Constraints When Deciding on PA Approach

The choice of technology and data capture methods should balance available resources, coaching needs, and level of detail required to answer desired performance questions. Therefore, a resource-driven approach is recommended, selecting methods that align with time, budget, and staff expertise and availability. For example, the increasing advanced video capture quality of personal cell phones could easily be used to capture land and bail outcomes. Optimally, to circumvent the complex and time-intensive manual coding of NA approaches, future development of microtechnology could be advantageous to automate this process.

Approaches should prioritise consistency and standardisation, with all practitioners trained accordingly.

7.4.3.1 Develop a Clear, Consistent Structure

A PA structure for street skateboarding should include trick naming conventions, trick classification (what constitutes a TA), and obstacle labelling.

7.4.3.2 Follow the Order of Importance

When deciding what performance details to capture, the following order of importance is recommended based on findings in latter chapters of the thesis.

- Record landed and bailed outcomes for TAs
- Capture both trick and obstacle attributes
    - Prioritise trick details in the following order:
        - The most efficient method is to classify tricks by their skateboarding name in real time
        - Supplement with additional traits (e.g., take-off stance, landing stance)
        - Build (or use an existing) trick database with broader grouping categories (e.g., flip trick, combination tricks)
            - A 3+ phased approach is recommended: take-off (TO), obstacle interaction(s) (IA), and landing (LD)
    - If time is limited, prioritise obstacle details in the following order:
        - Labelling feature vs. non-feature obstacles
        - Add obstacle types (rail, stairs, flat, etc.)
        - Link every TA to an obstacle
        - Link each TA phase to an obstacle

7.5 Chapter 5 Findings

7.5.1 Acknowledge Differences in the Men's and Women's Competition and Adjust Training Accordingly

Scores of the men's and women's competition significantly differed at the Tokyo Olympics, with men scoring higher than the women. Although these findings are yet to be confirmed in other competitions, coaches and skaters should consider how to differentiate themselves relative to their competitive skaters. Specifically, the men utilised more feature obstacles, performed a greater variety of tricks, including more combination and flip tricks, and attempted more tricks in varying stances. Although differentiating factors for performance between divisions is still underexplored, feasibly, due to the larger competitive history, men's skateboarding may represent a good model of performance trajectory for the women's competition.

7.5.2 Acknowledge Differences Between RUNs and BTs

Although seemingly obvious, researchers, coaches, and skaters should consider differences in performance by attempt format in training and competition. Greater obstacle variety was seen during RUNs. Moreover, bailing was more frequent during the BT section, likely attributable to greater trick variety (greater occurrence of varying stances, combination tricks, and flip tricks). PA approaches should be adjusted accordingly. For example, focused training approaches should be implemented to improve specific aspects of an individual's performance.

7.5.3 Follow Analytical Guidelines to Uncover Reliable and Valid Key Performance Patterns, Track Athlete Progression, and Understand Factors Contributing to Successful Outcomes

This section outlines recommended analytical guidelines to translate collected NA trick and obstacle data into meaningful performance insights. These approaches support consistent evaluation across competitions, facilitate comparisons between skaters of different skill levels, and enable a deeper exploration of the multi-dimensional nature of street skateboarding performance.

7.5.3.1 Use Both Raw and Standardised Scoring Methods

- Apply z-score or robust z-score standardisation to compare scores across rounds, divisions, and competitions
- Handle bailed BT attempts (0 pts) appropriately (possibly by removing them) during standardisation
- Use standardised scores to examine above- and below-average RUN and BT attempts
- Consider grouping by competition, division, round (e.g., semifinals, finals), and attempt type

7.5.3.2 Implement Intra- and Inter-Skater Comparison Methods

Use clear groupings to compare performance across skill levels and qualification status. For example, one could stratify skaters by qualification level across an Olympic cycle: Olympic Medalists, Finalists, Olympians, Phase 2 Qualifiers, and Phase 1 Qualifiers. Use multi-level scales of scoring, ranks, and attempt numbers to compare intra-skater performances.

7.5.3.3 There is More to a Score – Analyse Performance Across Multiple Levels

Understanding the many levels of scoring in street skateboarding competitions is crucial for valid performance analyses. These levels are presented below and should be understood by coaches and skaters when attempting to explore various aspects of performance through analytical approaches:

- ***ATTEMPT level (RUN/BT)***
    - RUN/BT Attempt Number
    - RUN/BT Attempt Score (0-100pts)
    - RUN/BT Standardised Attempt Score (e.g., -3 to 3, 0 = average)
    - Best RUN/BT (TRUE=contributed to ROUND score)
- ***ROUND level*** (e.g., OPEN, quarter-finals, semi-finals, finals)
    - Round place (rank)
    - Round score (0 to 100pts)
    - Normalised Round score (e.g., -3 to 3, 0 = average)
- ***DIVISON level***
    - Final competition placement
    - Qualification points awarded (based on final rank)
- ***QUALIFICATION PHASE level***
    - Phase 2 Qualified vs. not (i.e., Phase 1 Qualifier)
    - Olympian vs. Non-Olympian (i.e., Phase 2 Qualifier, Phase 1 Qualifier)
- ***QUALIFYING SERIES level***
    - WS rank (total qualifying points from the best 3 or 4 competitions)
    - Total WS points awarded

7.6 Chapter 6 Findings

7.6.1 Develop Feature Obstacle Proficiency

Feature obstacles were found to be a critical component of BTs during the Olympic debut. Moreover, their importance in RUNs is also apparent, but understanding to what extent requires more research. Utilising feature obstacles in RUNs does however appear to be a critical strategy for skaters to distinguish themselves from the competition in the womne's division. Therefore, coaches should implement training that facilities the use and consistency of tricks on and off of larger obstacles, particularly for female athletes.

7.6.2 Secure Scores Before Attempting Riskier Tricks

The number of landed TAs in RUNs was the strongest predictor of total RUN score, with bails being the single largest negative contributor for both divisions. RUN strategy should focus on completing full, clean RUNs, even if that means using lower-difficulty but consistent tricks, particularly in earlier rounds. More research is needed to explore the relationship of BT scores and bails. Although anecdotal evidence exists to the importance of bails during BTs (score equal to zero), practitioners could explore tactical strategies that may assist in improving BT scores, such as the order of tricks attempted.

7.6.3 Prioritise Consistency and Calculated Risk-Taking

When selecting which tricks to attempt and/or obstacles to use, skaters and coaches should prioritise consistency, especially if a full round score has yet to be completed. This may become even more critical in RUNs with the shift away from a 2/5/4 format and towards a 2/5/3 format, requiring skaters to count one RUN attempt towards their final round score.

7.6.3.1 Tailor Risk Strategies Based on Division

KPIs in RUNs and BTs varied by division. The women distinguished themselves from other skaters by using larger obstacles (BTs and RUNs), flipping their board (BTs and RUNs), and varying their take-off stance (RUNs). In comparison, the men separated themselves from the competition using combination tricks (BTs), leading to more unique trick types (RUNs). These KPIs may change as the sport evolves, but practitioners should continue to explore performance in the divisions separately.

7.6.3.2 Tailor Risk Strategies Based on Attempt Type

There were different KPIs in RUNs compared to BTs. Coaches and skaters should adjust their plans accordingly, balancing consistency and difficulty to align with scoring opportunities in each, such as prioritising trick variety during BTs and obstacle variety during RUNs.

7.6.4 Train Landing Mechanics

Chapter 6 highlighted the high number of trick attempts during an Olympic competition round, suggesting 8-9 trick attempts per RUN (in 45 seconds) was key to a high score. Moreover, the high landing forces evidenced in Chapter 2 further encourage the training of landing mechanics, in addition to eccentric strength to ensure skaters can consistently and safely land trick attempts.

7.6.5 Foster Variety and Novelty in Trick Selection

In Chapter 3, individual style was reported as being the greatest importance to performance in competition settings. This was reiterated in Chapter 6, with aspects of trick variety being critical to a high score. Moreover, the influence of bailed trick attempts should be weighed when implementing creativity through trick and obstacle selection. Creative strategies should be tailored towards the skater’s strengths and judging trends observed.

7.7 Street Skateboarding Performance Model Overview

A gold-winning street skateboarding performance is expectedly multi-faceted, with physical, technical, and tactical foundations required, evidenced by the findings in this thesis. Improving along any dimension requires a deep understanding of the sport, which is impossible for either practitioners or scientists in isolation. To accommodate this, a framework should capture the key physical, technical, and tactical components as parts of an evolving whole; Figure 17 is our attempt at this, stylised as a skateboarding wheel. This model was designed to evolve with the evolution of the sport, with the ability to add and remove parts as performance inevitably changes. Moreover, performance is context specific, with differences by skill-level, discipline, division, and attempt type, made evident by Chapters 2 to 6. Therefore, this model and associated explanations focuses on elite, Olympic level street skateboarding for the men's and women's divisions, combined. Both RUN and BT KPIs will be discussed. All cross-over learnings, albeit expected, are speculation at this stage. Findings specific from the Tokyo Olympics are discussed below, with implications further described in the following section.

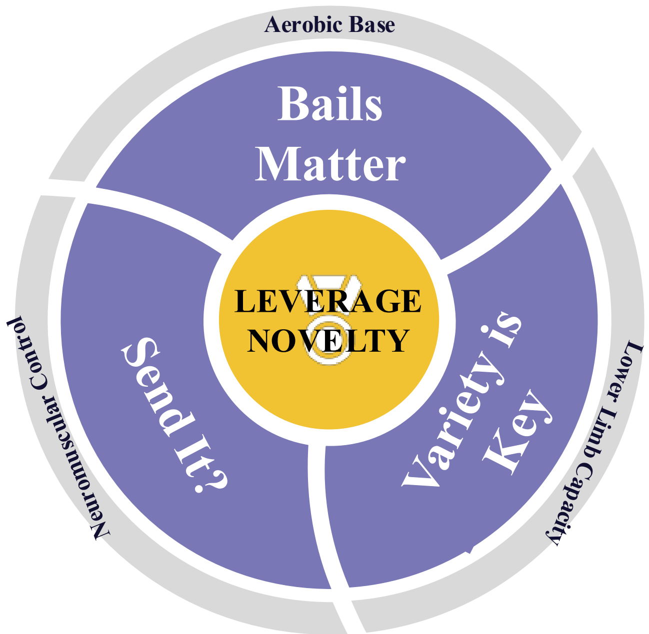


Figure 17: A proposed picture of performance for Olympic street skateboarding

7.7.1 Gold Winning Performance

At the heart of the model is a gold-medal; that which the outer pieces surround, critical to the central goal. The key takeaway and guidance for aspiring skaters looking to achieve gold being to ***leverage their novelty***. In the judging criteria for competitive street skateboarding, novelty (the uniqueness and originality of tricks) is a valued component that can enhance overall impression scores. Successful athletes often possess a bag of signature tricks or combinations that differentiate them from competitors (Chapter 6). Leveraging novelty requires more than simply performing new or uncommon tricks; it likely demands strategic selection and tactical presentation to maximise judging impact without compromising execution quality.

Tricks that only a particular skater can perform, or tricks rarely seen in competition, could create a distinct competitive advantage. However, novelty must always be balanced with technical proficiency. Poorly executed novel tricks are unlikely to earn high scores and may increase the risk of bailing. Coaches and athletes should focus not only on the creation of new trick variations but also on consistent, high-quality execution under competition pressure.

Finally, novelty should be tactically showcased. Skaters might consider saving particularly novel tricks for high-stakes moments, such as later rounds or BT attempts, to maximise scoring potential and psychological impact on both judges and competitors. Whilst technical and tactical skills support the *what* and *how* of competitive success, it is the skater's physical capacities that likely determine *whether* these strategies can be executed reliably, consistently, and safely.

7.7.2 Physical Demands

Not only is novelty reflected in many judging criteria (e.g., originality, style, variety, etc.), but Olympic and amateur skaters agree that style is the most important for performance (Chapter 3). As previously demonstrated, style is underpinned by many subjective and objective performance factors; by which most could potentially be leveraged through targeted physical development (e.g., speed, height, distance, power, aggression, quality of landing). In particular, (1) an aerobic base (2) lower limb power, strength, and flexibility, and (3) neuromuscular control could be key to perform single high-risk, technically challenging tricks (BT) and in succession (RUNs). Moreover, improved physical capacities likely open opportunities for new tricks as well as greater control between transitioning of tricks. However, these physical demands are speculation at this stage, and as such, are presented here as an example. Future research is needed to explore the relationship of physical capacities and technical and tactical demands.

7.7.3 Technical and Tactical Demands

RUN and BT Tokyo Olympic gold medal winner performances for the men's and women's divisions are presented in Figure 18 through Figure 20.

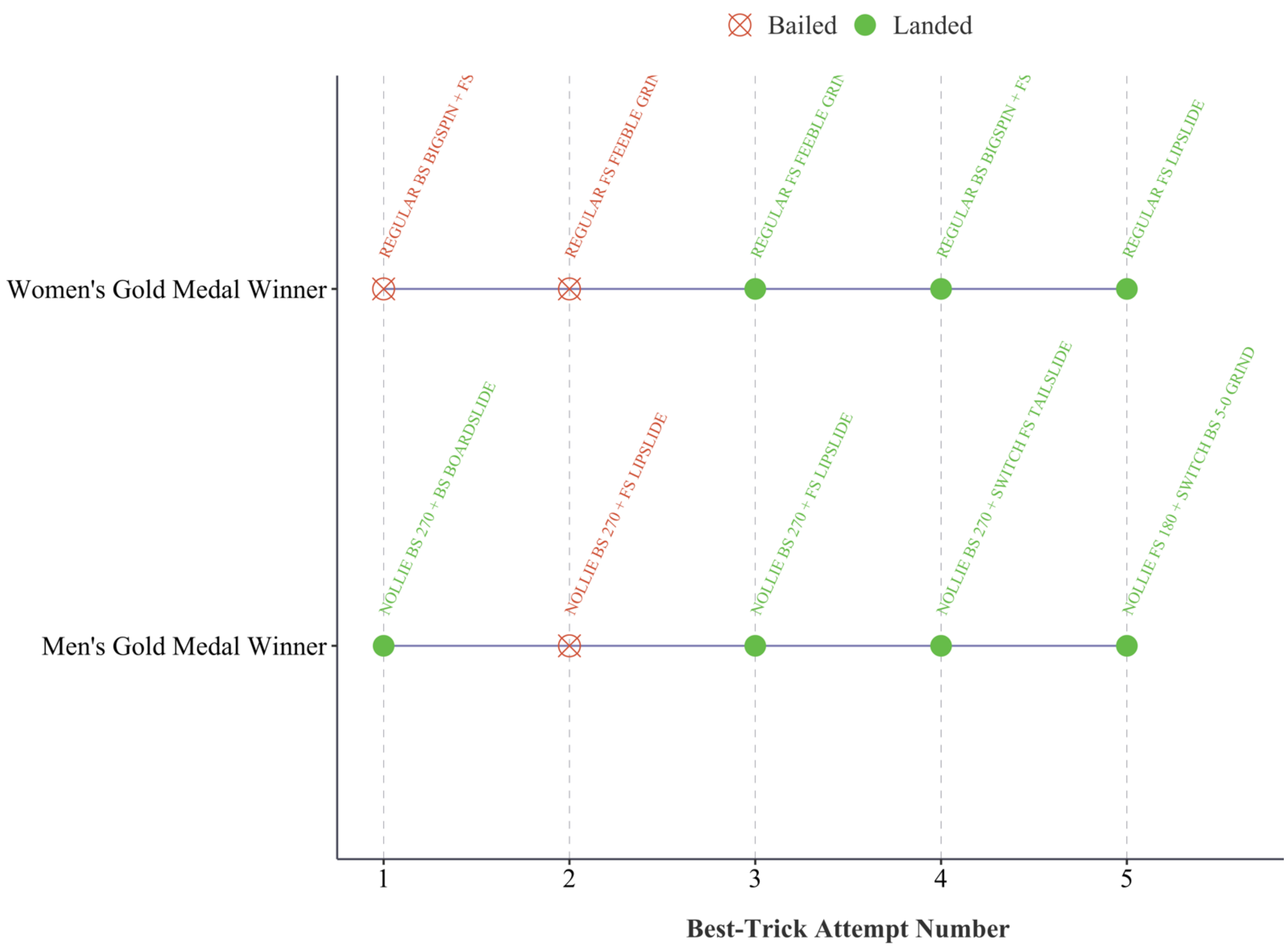


Figure 18: Men's and women's gold-medal winner best-trick attempts from the Tokyo 2020 Olympic debut of street skateboarding. All trick attempts were attempted on a feature, larger obstacle.

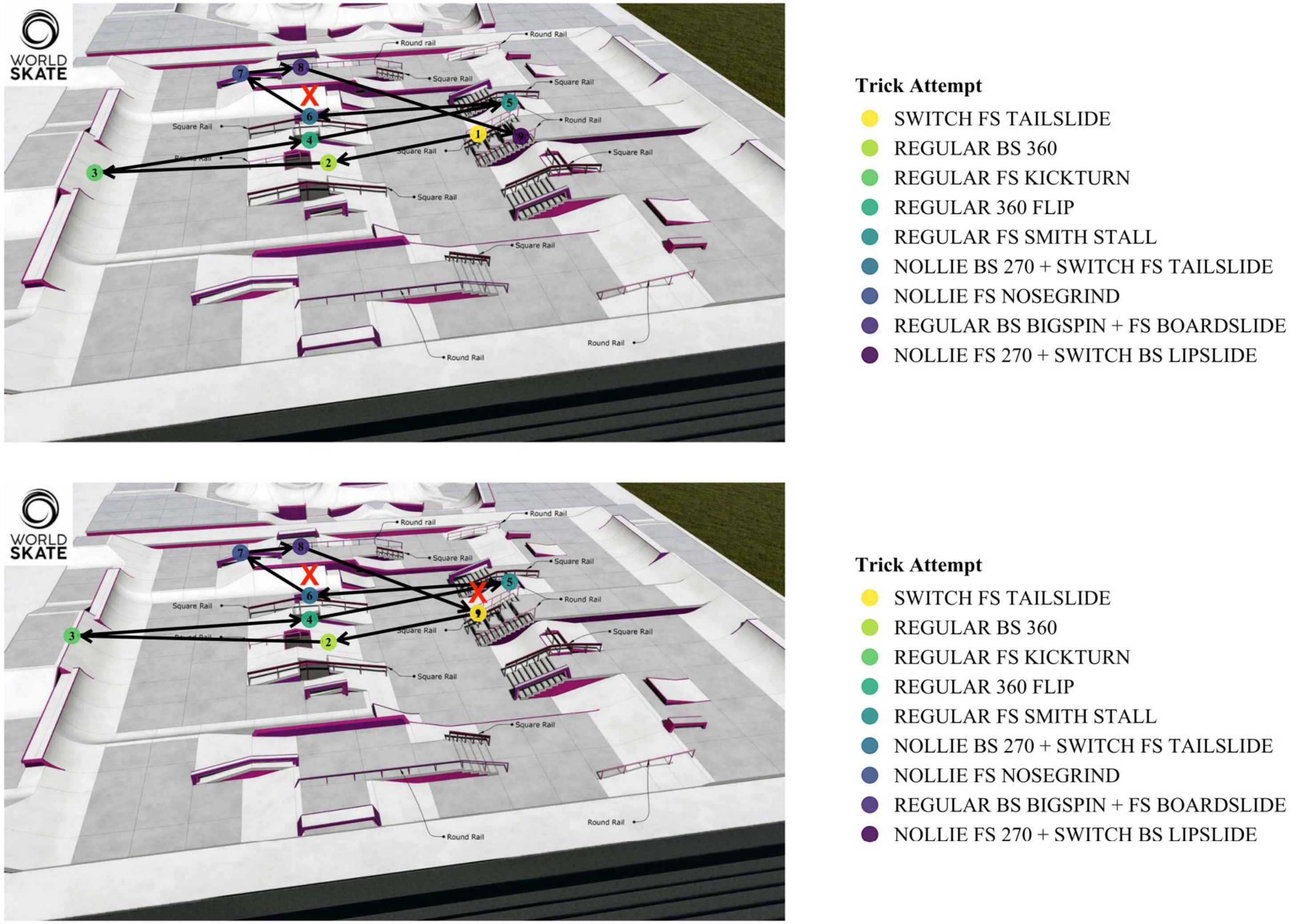
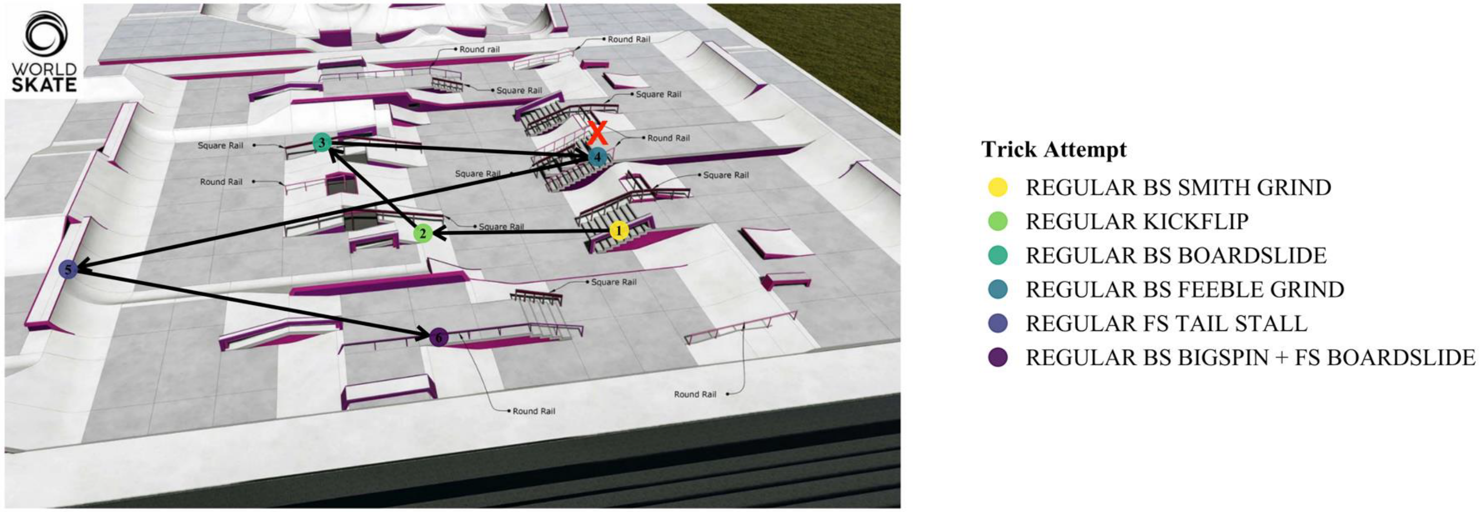


Figure 19: *Men's* gold-medal winner run attempts (top=first attempt, bottom=second attempt) from the Tokyo 2020 Olympic debut of street skateboarding. Bailed tricks are shown with an 'X' above the trick attempt point.



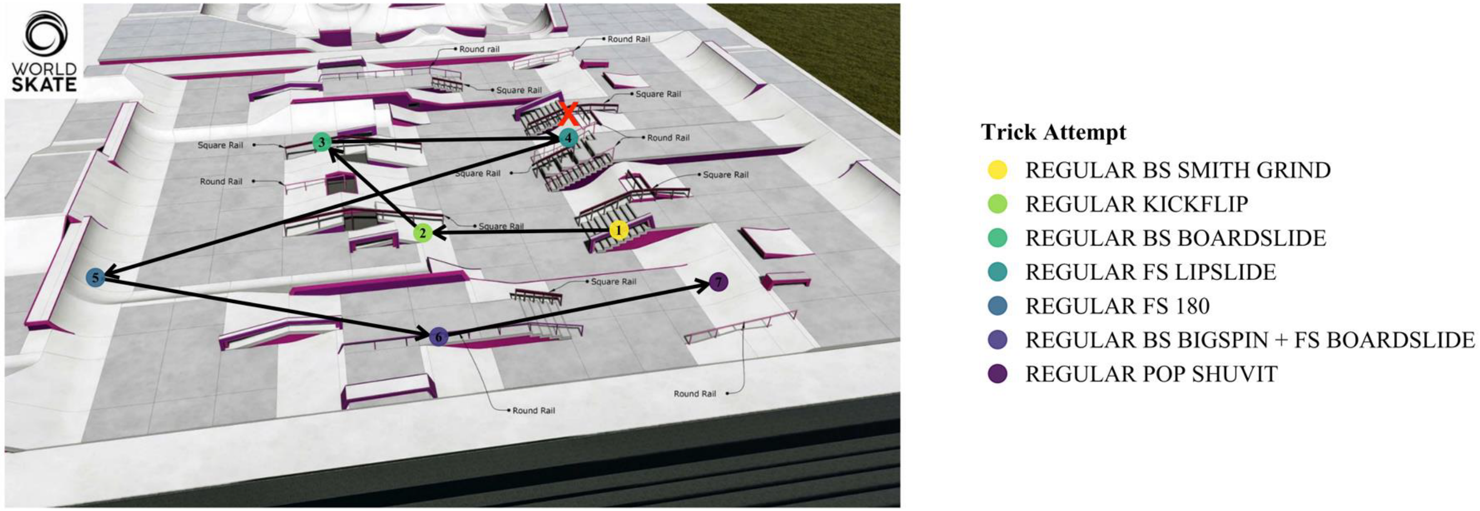


Figure 20: *Women's* gold-medal winner run attempts (top=first attempt, bottom=second attempt) from the Tokyo 2020 Olympic debut of street skateboarding. Bailed tricks are shown with an ‘X’ above the trick attempt point.

7.7.3.1 Bails Matter

Not surprisingly, bailing in street skateboarding is inevitable and fundamental to performance. At the Tokyo Olympics, the frequency of bailed trick attempts (TA), termed 'consistency', emerged as the largest contributor to RUN scores for both men and women. Accordingly, when planning for competition, it is recommended that skaters prioritise securing a complete RUN score, even if this requires selecting slightly less difficult but more consistent trick options.

Whilst the relationship between bails and performance in BT attempts has not yet been systematically examined, any bailed TA receives a score of zero, resulting in a clear and direct negative impact on overall competition outcomes. Thus, like RUN strategy, it is advisable that skaters first aim to get a complete score on the board (e.g., 2 or 3 BTs), before attempting more difficult tricks that carry a higher risk of bailing.

From a PA perspective, bails should not be overlooked. Future research should explore not only the frequency of bails but also their timing relative to scoring outcomes. For instance, skaters who bail on initial attempts at a difficult trick may subsequently receive higher scores upon successful completion, potentially influenced by judging bias or crowd engagement effects observed in other judged Olympic sports [153]. Coaches could look at bail timing and resulting impacts for their athlete to understand how to sequence trick attempts based on their consistency, to optimise scoring potential. A physiological component is likely related to performance across trick attempts as well, and skaters may benefit from targeted training to address any potential fatigue-related performance decrements.

The evolving structure of competition formats also warrants consideration. The BT section was purportedly designed to accommodate occasional bails, encouraging skaters to attempt their most technically demanding tricks and thereby promoting progression within the sport. The transition from the 2/5/4 to the 2/5/3 format has likely amplified this effect, as skaters now need only two successful BT attempts to contribute to their round score. Additionally, the consistent weighting of BT scores, always representing two-thirds or less of a skater's total round score, provides strategic implications for training. Specifically, higher-risk tricks might be periodised not only to manage the associated physical demands [24] but also the psychological and emotional load inherent in bailing [105].

Finally, understanding the role of bails is critical when evaluating other technical and tactical KPIs discussed in the following sections. The integration of bail analysis into coaching strategies and performance monitoring will likely be essential for optimising success in modern competitive street skateboarding.

7.7.3.2 Variety is Key

Variety, both in obstacle and trick selection, is a critical performance element recognised by judges and the skateboarding community alike. A diverse performance demonstrates an athlete's technical versatility and adaptability to the course environment. However, how and when skaters should introduce variety appears to depend on factors such as division, skill, and tactics.

At the Tokyo Olympics, skaters in then womne's division exhibited greater obstacle variety during the BT section. Despite this, higher scores were consistently awarded to both men and women who utilised larger, feature obstacles, suggesting a hierarchy in the judging criteria for BT attempts. Accordingly, it is recommended that athletes introduce variety primarily through trick selection in BT rounds whilst prioritising the use of prominent obstacles to maximise scoring potential.

A similar, yet strategically distinct approach was observed in RUN attempts. In the women's division, incorporating feature obstacles was strongly associated with higher RUN scores. In contrast, among men, the total number of unique trick types, rather than obstacle selection, was more predictive of higher scores. This pattern likely reflects the relative skill levels between divisions and the hierarchical application of judging criteria. Less skilled skaters tended to place less importance on trick originality, whereas elite athletes recognised originality as a key contributor to competitive success (Chapter 3).

Moreover, trick variety often serves as a vehicle for skaters to leverage novelty. For instance, at Tokyo, skaters in the women's division that introduced variety through different stances were rewarded, possibly because few competitors possessed this skill. Similar advantages were seen with the use of feature obstacles, flip tricks, and combination tricks; areas where individual capacity to diversify set leading female skaters apart. Among men however, such elements were more common and thus did not distinguish top performers to the same extent. This aligns with elite skaters' self-reported values in Chapter 3, suggesting that originality appears increasingly important for distinguishing success at higher competitive levels.

As the sport evolves and particularly as the women's division progresses rapidly, it is likely that both divisions will converge in their strategic use of variety and novelty. Over time, performance differentiation may shift away from fundamental physically-limited capabilities towards more creative and original trick executions. As such, one recommendation for skaters in the women's division would be to prioritise development of key physical capacities, lower body strength, power, and flexibility.

Ultimately, trick and obstacle variety should be applied strategically, considering the competition round format, division-specific judging trends (when relevant), and individual skater strengths. Decisions around variety should support a broader tactical approach aimed at maximising score potential whilst effectively managing risk.

7.7.3.3 Deciding Whether to 'Send It'

The concept of "sending it" refers to the calculated pursuit of high-risk, high-reward performance strategies; a hallmark of elite-level street skateboarding [154]. Tactical risk-taking is particularly relevant when selecting large, feature obstacles and attempting technically demanding tricks, especially during BT attempts where single high-value tricks can substantially influence round rankings.

A key tactical consideration is the differing risk profiles between RUN and BT attempts. RUN formats reward consistency and flow, whilst BT formats allow skaters to capitalise on isolated moments of high difficulty and reward, often making "going big" more advantageous in BT attempts. Division-specific considerations also play a role, as Chapters 5 and 6 suggest potential differences in trick selection, risk tolerance, and scoring patterns between the men and women. Coaches should tailor risk strategies accordingly.

Whilst embracing risk is essential for competitive success, it must be approached judiciously. Skaters and coaches should use performance models; such as the one presented in this guide, to evaluate the potential benefits of high-difficulty tricks against the increased probability and consequences of bails, particularly during RUN attempts where consistency carries greater weight. Ultimately, "sending it" should be viewed not as reckless pursuit of difficulty but as a sophisticated, strategic decision embedded within a broader performance plan.

7.8 Conclusion

By aligning physical preparation, technical development, and tactical planning, skaters and coaches can systematically enhance aspects of performance. Whilst creative freedom should be encouraged, the guidelines provided in this chapter are the beginnings of a structured foundation to support competitive skateboarding success. To ensure these strategies are effective and evolve with the sport, ongoing performance monitoring is essential. To support continuous improvement and ensure training aligns with competition demands, performance monitoring should integrate technological tools and standardised analytics to provide actionable insights to stakeholders.

CHAPTER 8:

SUMMARY, REFLECTIONS, AND FUTURE RESEARCH DIRECTIONS

Prelude:

As the first comprehensive investigation into competitive street skateboarding performance, this thesis established foundational methods to objectively describe and evaluate success. This final chapter reflects on the key findings, situates them within the broader sporting and research landscape, and reflects on the learning and opportunities to guide future research and practice.

CHAPTER 8: SUMMARY, REFLECTIONS, AND FUTURE RESEARCH DIRECTIONS

8.1 Summary of Thesis Take-Aways

This thesis provides answers, partial and full, to the questions originally proposed, which are listed below. The answers here are straightforward and summarised, based on the findings, discussions, and conclusions within each experimental chapter:

1. ***What are the known physical, technical, and tactical demands of competitive skateboarding based on the current literature?***

   The literature pertaining to demands underpinning competitive performance **remains limited**, however this thesis does add to the understanding of these demands, and provides an overview of the current available empirical knowledge. Skateboarding is a technical, skill-based sport, requiring athletes to produce force effectively and efficiently to move with their board in a variety of ways. Physically, skaters likely require quick and high force outputs of the lower limbs, in addition to a large range of motion, drawing on anaerobic energy sources to successfully perform and land flip and combination tricks often interacting with larger, feature obstacles; a critical component of success in Olympic competition. Notably, the tactical demands of competitive skateboarding explored in this thesis pertain to the street competition. Despite likely cross-over between park and street disciplines, competitive skateboarding should be broken down respectively to accurately reflect the unique characteristics and underlying demands of each. With that in mind, more discipline-specific research is needed to understand the nuances of performance within street and park contexts.

2. ***How do skaters and community members perceive success in competitive skateboarding, and what are the implications for performance evaluation and training?***

As with most subjective, artistic sports, competitive **perceptions of success (e.g., winning) are individualistic;** World Skate judging criteria generally reflected what skaters perceive as important to competitive success. Whether this is an agreement between communities, or a product of competition structure, is unclear. One argument for the latter is the notable discrepancy concerning emphasis on the number of tricks performed within a run; skaters did not find this important to recreational skating success. However, what is consistent across both competitive and recreational skateboarding is the perceived importance of flow and style. Nevertheless, the order and magnitude of importance for various criteria remains ambiguous. The notational framework developed in the latter chapters of the PhD begin to explore objective measures of flow and clutch states that may help to shed a light on the effective weighting of criteria and allocation to overall impression scores. As training practices currently align with what skater's feel are important for success, which appears to vary by experience (skill-level, discipline, and community involvement), more research is needed to fill in the gaps to support practitioners and skaters towards identifying trainable aspects of performance, including underlying physical, technical, and tactical demands.

a. ***Do perceptions of success differ by discipline (street vs park), skill level (amateur vs professional), or level of community involvement (competitive vs recreational)?***

Yes, it would appear so. First, perceptions of success in competitive skateboarding differ by skill. Elite skaters emphasised originality and variety, amateur skaters likely focus more on fundamentals, and may be limited in their access to resources, competitions, training, and support by which would influence their views on what constitutes performance. When stratified by discipline, street skaters highlighted aesthetics and originality, whilst park skaters indicated that more physically-underpinned criteria such as power and trick height were more important. Interestingly, these differences may also help to explain division-based differences from the Olympic street debut, identified in Chapters 5 and 6. Successful women run and best-trick attempts were those that incorporated larger, feature obstacles, flip tricks, and varied stances, all of which require a level of technical and physical capacity to consistently land (as found in Chapter 2). In comparison, success in the men's division was not as clearly defined. Feature obstacles were used by all male skaters, resulting in novelty and variety discriminating performances instead. A common theme across all participants however, is that skaters currently focus their training on what they perceive is important for competitive performance. Therefore, an objective understanding of what distinguishes success within skill, discipline, division, and community contexts is critical to ensure skaters are training effectively for their respective environments.

3. ***Can a NA framework be developed to reliably describe key components of street skateboarding performance?***

   Yes, to an extent. In Chapter 4, a standardised means of classifying trick, obstacle, and execution aspects of street skateboarding performances was created. Whilst reliable, the approach requires a deep skateboarding specific knowledge base to accurately capture nuances of the sport. If practitioners are to implement such an approach (e.g., across multiple individuals), clearly defined rules for identifying and naming trick attempts is crucial. Integrating automation into aspects of the proposed framework may also be advantageous.

   a. ***To what extent can this framework capture aspects of flow and style that are influential in judging outcomes?***

      Temporal aspects of flow and style were reliably captured with the proposed framework, with various caveats. Trick attempt take-off and landing moments can be reliably captured by notating broadcast footage. Nevertheless, interactions with obstacles (particularly copings) were less reliable, and do appear to be impacted by rater experience. Also, findings from the later chapters in this thesis suggest that whilst temporal measures of trick attempts may impact performance, the relationship is complicated. For example, time itself is probably a proxy for other more discriminate measures (e.g., speed, flow, etc.), which are more difficult to measure through NA alone. Therefore, other technologies to directly measure speed, such as GPS, should be explored.

4. ***What are the defining characteristics of elite performance in Olympic street skateboarding?***

At a fundamental level, elite performance in street skateboarding is underpinned by **landed and bailed tricks**. Specifically, success appears to be related to a skater's ability to navigate the risk vs. reward trade-off inherent within the competition format, with more successful tactical strategies seemingly dependent on division and attempt type. Elite skaters leverage their novelty by diversifying trick and obstacle selection in all phases of tricks; take-off, obstacle (or air) interaction, and landing. Such strategies include varying take-off and landing stances, flipping their board (into, during, and out of other tricks), and performing a range of trick types (e.g., grinds, slides, flips, etc.), which inherently requires a range of obstacles. Notably though, skaters must be able to interact with the largest obstacles in the park, during both run and best-trick attempts.

5. ***How do performance strategies and scoring patterns differ between the men's and women's street competitions?***

When judged on the same scale, **men's scores were significantly higher**. Associated factors underpinning these scores also differed. Olympic men demonstrated greater "novelty", as variety in trick selection (trick types, stances, etc.). Women demonstrated wider obstacle variety, particularly during BT attempts; however, the value of feature obstacles revealed wider obstacle use was less than optimal. Flip tricks appeared to be more discriminating in the women's event also, likely due to their infrequent execution among competitors. Ultimately, success among women was associated with the ability to perform flip tricks incorporating feature obstacles. However, scoring and competition formats have evolved, so future research might explore whether performance determinants have changed in tandem.

a. ***Which objective performance metrics best predict success in RUN and BT attempts?***

Objective performance metrics associated with success in RUNs include the **number of trick attempts** (sweet spot between 8 and 9 at the Tokyo Olympics), and **fewer bails**. In contrast, BT success appears less penalised by bails and is more influenced by trick difficulty and **use of feature obstacles**. Beyond this, performance is moderated by division (sex).

8.2 Reflections (Limitations)

Competitive street skateboarding performance is inherently complex. Scoping an objective association of performance to success is difficult and compounded by the sport's relative newness, resulting evolution, and limited scientific literature. This thesis built a framework by which street skateboarding could be classified and aspects of performance could be measured and associated with success at the Olympic debut. However, inevitably, this approach does not capture all factors related to competition outcomes. Moreover, of the factors that were captured, scientific rigor necessitated focusing on select ones whilst controlling for interactions, further restricted by sample size limitations. Therefore, the scope and boundaries of the thesis should be considered when implementing findings into practice.

8.2.1 Evolution

The rapidly evolving nature of competitive street skateboarding must be considered when interpreting the learnings from this thesis. Since its Olympic debut, the sport has undergone considerable transformation in terms of format, judging standardisation, and athlete performance, particularly among the women's division. Whilst studies in this work predominantly utilised data from the Tokyo 2020 Games, the competitive landscape has continued to mature. Accordingly, it might be assumed judging panels may have become more experienced and consistent, formats having been refined, and the overall level of performance may have progressed. Importantly, judging criteria were designed to accommodate and even promote such evolution in performance. Accordingly, as the organisation and structure of competitions progress, the relationship between performance outcomes and bails may also evolve. It is plausible that future competition designs may aim to reduce the frequency or impact of bails on RUN scoring, necessitating a re-evaluation of how success is objectively measured. Although the current framework was evaluated on a single competition, it was designed to remain adaptable for future iterations of the sport. As such, the findings presented here provide a foundation upon which future research and performance analyses can build, offering both methodological and conceptual guidance for investigating the ongoing evolution of skateboarding performance.

8.2.2 The Role of Bails

During the Tokyo Olympic debut, almost a quarter of all trick attempts were bailed; 55% of BTs and 14% of individual tricks during RUNs. These ratios suggest bailed tricks are equally important to performance as landed tricks (Chapter 6 and Chapter 7). Furthermore, as seen in other high-risk action sports [155], bails likely play an even greater role in training environments as skaters develop and refine new tricks for competition. Nonetheless, despite their seemingly central place in performance, this thesis did not examine bails beyond their proportion relative to total trick attempts. Consequently, this was a clear limitation in fully describing performance. Nevertheless, the proposed framework enables the collection of critical bail data, including the trick phase in which a bail occurs. Future research should investigate bails in greater detail to better understand their influence on tactical strategy, training, and injury.

8.2.3 Interaction Effects: Tricks, Obstacles, and Contextual Complexity

Skateboarding is a freestyle, subjectively assessed competitive sport, where style and flow underpin performance. Inevitably, there are aspects of performance which are likely impossible to measure objectively, and arguably should not be. Therefore, prioritisation is necessary to identify and measure the most critical performance components. Being the first PA of skateboarding and without a-prior empirical guidance of important aspects, this work focused on fundamental elements of the sport, driven by a limited sample size. As a result, interaction effects, such as trick and obstacle selection, were not explored. Nevertheless, the inextricable relationship between tricks, obstacles, and execution cannot be overstated, and the lack of interaction analysis may limit the broader applicability of the findings. As such, caution is advised when applying the findings from this thesis to avoid adopting an overly reductionist view of skateboarding performance. However, these limitations do not detract from the usefulness of the established PA framework, the clear description of technical performance, and the fundamental KPIs presented, elements on which future research can build and practitioners can adapt for their specific contexts.

8.2.4 Technological Constraints and Analytical Trade-offs

This thesis work leveraged publicly available and high-quality footage of the best athletes in the world. As such, the work provides a unique and accessible picture of performance, that may not have been otherwise possible, and signals promise for future researchers and practitioners. Nonetheless, the technological approach has constraints. In addition to a single stream, multi-angle capture volume making some aspects of NA difficult, more notably, time costs associated with the NA approach limited the scale and depth achievable within the timeframe of this thesis. Future researchers should explore scalable solutions, including the automation of NA and potential integration of microtechnology, which may enhance the efficiency and add further granularity to the understanding of skateboarding profession and performance variability across competitive contexts.

8.2.4.1 Opportunities for Automation

As described above, whilst NA was adopted with some success in this thesis, and hence provides a feasible means of characterising performance, it has some limitations (several of which have been introduced above). Notably, it is highly time-intensive and requires considerable domain knowledge in skateboarding (Chapter 4) to accurately code and interpret performances [156]. This restricts scalability, particularly when large datasets or multiple competitions are involved. Furthermore, variability introduced by differences in analyst expertise highlights the need for standardised protocols and clearer operational definitions. Some aspects of performance, such as nuances in trick execution, speed, or athlete intent, are either difficult to quantify or entirely unobservable using NA alone, thereby potentially limiting the completeness of the approach, particularly of Chapters 5 and 6.

In response to these limitations, future research should prioritise the development of automated methods to improve the efficiency, reliability, and scalability of PA in skateboarding [70]. One promising approach involves combining inertial measurement units (IMUs) and machine learning (ML) techniques. IMUs typically comprising accelerometers, gyroscopes, and magnetometers, can capture tri-axial data related to movement and orientation. Through sensor fusion techniques, they offer precise, real-time spatiotemporal information [157]. This is particularly valuable in freestyle board sports, where IMUs have been effectively used to classify tricks and quantify temporal KPIs such as airtime and trick duration (Chapter 4) in surfing [32, 158, 159] and snowboarding [34, 160, 161]. Given the shared biomechanical and stylistic demands across board sports, these metrics; explicitly linked to judging criteria such as "height" and "difficulty", are relevant in competitive street skateboarding (Chapter 3). This suggests that providing coaches with temporal KPIs via automated tools could support more targeted, real-time feedback and enhance training effectiveness.

Recent studies have demonstrated the feasibility of combining board-mounted and body-worn IMUs with supervised ML models to classify fundamental skateboarding tricks, such as ollies, kickflips, and shuv-its [54, 162-168]. However, many of these studies suffer from ecological limitations; they often use single-subject designs, are conducted in laboratory settings, and lack contextual elements such as obstacles, now known to be critical to success (Chapter 6). Moreover, Chapter 4 showed reduced reliability when measuring temporal components of obstacle interaction (e.g., grind time), limiting the utility of NA alone in capturing such measures reliably.

In a notable example of progress, Hu, Liang [47] successfully used a shank-mounted IMU to detect TO and LD events during an ollie, with promising accuracy. However, this study was again restricted to flat-ground tricks in a lab setting [47]. To advance the field and provide practical solutions for coaches, future researchers should validate these approaches in realistic competitive environments. This approach would allow practitioners to further explore the inextricably-linked relationship of speed with obstacle and trick measures.

The expansion of measurable KPIs again raises the issue of statistical power. As the number of confounding factors grows, it becomes increasingly difficult for coaches to translate raw data into actionable insights. ML offers a scalable solution, enabling pattern detection across large, complex datasets [169]. In particular, supervised learning methods can be used to predict outcomes (e.g., attempt scores) from NA-coded performance metrics, building upon the approach and findings in Chapter 6 [148].

In addition to prediction, interpretability is critical in judged sports. ML models must not only perform well but also provide insight into how decisions are made. This is particularly relevant for understanding the subjective components of judging, as addressed in Chapter 3. Interpretable models such as linear regression, decision trees, or ensemble methods (e.g., XGBoost [170]) offer a balance between predictive power and transparency, and have already shown promise in broader sports analytics [171, 172]. Although not yet widely applied to freestyle board sports, their potential to explain RUN and BT score variation in Olympic data (Chapter 6), whilst handling missing data [173] (a limitation identified in Chapter 4) is significant. Moreover, such models could be tested across different competition datasets to assess performance evolution and judging consistency.

Despite the potential of automation, it is essential to balance objective measurement with the subjective nature of skateboarding. Chapter 3 emphasized the centrality of style and flow, but attempts to quantify them risk undermining the very ethos that makes the sport unique [174]. Thus, automated systems must accommodate individual expression without introducing excessive burden to coaches and support staff [29]. Calibration techniques [54] show early promise, but future work is needed to ensure that automation technologies are both accurate and contextually relevant.

In summary, whilst NA remains a foundational and valuable tool, a hybrid approach integrating sensor technologies (IMUs), ML, and human expertise could improve the reliability of performance measures (limitations of Chapter 4), increase the scale to which the tool could be used (limitations of Chapter 5 and Chapter 6), and allow access to other potentially discriminating performance aspects. The NA framework proposed in Chapter 4 in combination with the technical and tactical performance indicators outlined in Chapters 5 and 6 provide a robust base to guide such development. Moreover, discipline-specific findings in Chapter 3 suggest that adapted technology may also support PA in park skateboarding. Ultimately, a more autonomous, scalable, and context-sensitive approach is not only feasible, but essential for advancing skateboarding science and effective coaching practices.

Collectively, these limitations underscore the need for continued exploration into the evolving demands of street skateboarding and highlight specific opportunities for future research to refine, expand, and adapt current frameworks for PA.

8.3 Suggestions for Future Research

This thesis has presented several questions and avenues for future research to investigate:

- *Has performance evolved with the changing landscape of Olympic skateboarding? Are KPIs consistent with Paris 2024 competitions? How has performance changed from the "2/5/4" format in the Tokyo 2020 Games compared to the "2/5/3" format adopted for the Paris 2024 Games?*

- *How do bails impact judging overall impression scores? How does the timing of bails relate to score? How can skaters leverage bails to their advantage? What can be learned from bailed trick attempts; are some tricks riskier than others? And how does this relate to the potential increase in score?*

- *How does speed relate to success in competitive street skateboarding, and can speed be accurately measured?*

- *What physical capacities underly performance success in street skateboarding? To what degree do these physical factors limit aspects of performance (e.g., utilise feature obstacles and/or perform combination tricks)?*

- *How do the performance aspects identified in this thesis relate to injury? Are certain trick and obstacle types associated with greater injury risk?*

- *How do the findings from this research relate to park skateboarding, a full run-based discipline? Are there distinct underlying capacities required for street and park, respectively? Moreover, how do these underlying capacities relate to competition performance?*

    - *Since bails fully terminate a run attempt in park skateboarding, how does the relationship of bails and score differ from street runs?*

- *What tactical strategies do more successful skaters implement? Do more successful street skaters perform tricks of lesser difficulty in earlier rounds? How do more successful street skaters navigate the risk vs. reward relationship during best-trick and run attempts, respectively?*

- *To what extent has the progression of women's performance reduced the technical gap relative to the men's division? Have KPIs converged with those seen in the men's division? Has progression in the women's division mirrored or diverged from the trends observed the men's division?*

- *To what extent can automated technologies and machine learning approaches be used to classify and quantify street skateboarding?*

- *How can machine learning be leveraged to support PA of skateboarding?*

8.4 Conclusions

The overarching aim of this thesis was to identify what constitutes a successful performance in competitive skateboarding. With no established evidence to draw from, this research ***dropped in*** by systematically investigating the physical, technical, and tactical demands of elite-level street skating (Chapter 2). A critical gap in the literature was identified, with a clear need to explore the tactical demands of elite-level competition before understanding the importance of underlying technical and physical characteristics. Subsequently, Olympic, amateur, and recreational skaters were surveyed to understand their perceptions of performance, by which judging criteria were purportedly developed (Chapter 3). Style and flow were unequivocally the most important across all groups, however ambiguity in what constitutes a better competitive performance remained, accentuated within the Olympic cohort. Moreover, there were variations between skaters, skill-levels, and disciplines regarding their perceptions and those of judges during competition, like the importance of the number of TAs within a RUN. The lack of tactical knowledge and ambiguity from the community meant a clearer understanding of performance was needed for skaters to effectively train for the specific demands of competition.

To **get set**, a foundational PA framework was developed (Chapter 4), enabling the structured classification of trick selection, obstacle selection, and execution. This framework allowed for the first empirical investigation into how performance is expressed and evaluated in Olympic competition, with a focus on the street discipline. A NA framework was developed and tested using data from public broadcast footage of the skateboarding Olympic debut (semi-finals round) to quantify outcome-related aspects of judging criteria. A mixed-methods approach was used to identify key elements of street skateboarding skill; obstacle, skater, trick attempt, outcomes, and time, by breaking down movement into take-off, obstacle interaction, and landing phases. This PA approach allowed users to uniquely define street skateboarding and quantify performance aspects of judging criteria, including subjective elements of style, without sacrificing skateboarding nomenclature. However, whilst this approach showed promise, caution was needed when extracting temporal features; notably, a single, experienced user could capture TO and LD, but IA may not be reliable.

These findings were **sent into** action by applying the PA framework to capture and understand performance from the men's and women's divisions of the Tokyo Olympics. Key findings revealed that performance is not only shaped by the format of the attempt; RUN or BT, but also by skater discipline (Chapter 3) and division (Chapter 5). Successful street performances were characterised by the strategic use of feature obstacles, demonstration of individual novelty, and an ability to navigate the inherent risk–reward trade-off through intentional trick and obstacle selection (Chapter 6).

Finally, the thesis **landed bolts** by delivering novel, actionable insights that can inform future research, coaching practice, and performance development (Chapter 7). As the sport continues to evolve, the factors associated with success are also likely to change. Future research can build on this foundation by developing scalable, automated approaches leveraging wearable technology and machine learning; examining bails as a tactical element; and applying and refining the framework across diverse and evolving contexts. Whilst there is still more to learn, the groundwork established in this thesis not only advances the current understanding of performance, but also lays the foundation for innovative approaches that will shape the future of competitive skateboarding.

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APPPENDICES

Appendix I: Ethics Approval

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
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1 November 2022

Matthew Cross
Faculty of Health and Environmental Sciences

Dear Matthew

Re Ethics Application: **22/248 Defining skateboarding performance success: A community perspective**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 1 November 2025.

Non-Standard Conditions of Approval

1. On the survey please replace the sentence "waiving consent" with "Submitting the survey implies consent to participate".

Non-standard conditions must be completed before commencing your study. Please send through the updated version for our file.

Standard Conditions of Approval

1. The research is to be undertaken in accordance with the Auckland University of Technology Code of Conduct for Research and as approved by AUTEC in this application.
2. A progress report is due annually on the anniversary of the approval date, using the EA2 form.
3. A final report is due at the expiration of the approval period, or, upon completion of project, using the EA3 form.
4. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form.
5. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
6. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.
7. It is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard and that all the dates on the documents are updated.
8. AUTEC grants ethical approval only. You are responsible for obtaining management approval for access for your research from any institution or organisation at which your research is being conducted and you need to meet all ethical, legal, public health, and locality obligations or requirements for the jurisdictions in which the research is being undertaken.

Please quote the application number and title on all future correspondence related to this project.

For any enquiries please contact ethics@aut.ac.nz. The forms mentioned above are available online through http://www.aut.ac.nz/research/researchethics

(This is a computer-generated letter for which no signature is required)

The AUTEC Secretariat
Auckland University of Technology Ethics Committee

Cc: shelley.diewald@aut.ac.nz

Appendix II: Publication Abstracts

CHAPTER 2: SKATING INTO THE UNKNOWN: SCOPING THE PHYSICAL, TECHNICAL, AND TACTICAL DEMANDS OF COMPETITIVE SKATEBOARDING

The inclusion of skateboarding in the Olympics suggests that athletes and coaches are seeking ways to enhance their chances of succeeding on the world stage. Understanding what constitutes performance, and what physical, neuromuscular, and biomechanical capacities underlie it, is likely critical to success. The aim was to overview the current literature and identify knowledge gaps related to competitive skateboarding performance and associated physical, technical, and tactical demands of Olympic skateboarding disciplines. A systematic scoping review was performed considering the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (Extension for Scoping Reviews) guidelines. Data sources were MEDLINE (Ovid), Scopus, SPORTDiscus, and PubMed. We included all peer-reviewed literature after 1970 describing the physiological, neuromuscular, biomechanical, and/or tactical aspects of skateboarding. Nineteen original articles explored the physiological (n = 9), biomechanical (n = 8), and technical (n = 10) demands of skateboarding. No research explored the tactical demands of competition. Moreover, although competitive males (n = 2 studies) and females (n = 1 study) were recruited as participants, no research directly related skateboarding demands to performance success in competitive environments. Ultimately, what constitutes and distinguishes competitive skateboarding is unexplored. There is some evidence indicating aspects of the sport require flexibility and elevated and fast force output of the lower limbs, which may be valuable when attempting to maximise ollie height. Nonetheless, a lack of ecological validity, such as using static ollie tests as opposed to rolling, restricted our ability to provide practical recommendations, and inconsistency of terminology complicated delineating discipline-specific outcomes. Future researchers should first look to

objectively identify what skaters do in competition before assessing what qualities enable their performance.

CHAPTER 3: EXPLORING PERCEPTIONS OF SUCCESS IN OLYMPIC COMPETITIVE AND AMATEUR STREET AND PARK SKATEBOARDING AND IMPLICATIONS FOR TRAINING

In competitive street and park skateboarding, judges determine success based on an 'overall impression' of each skater's performance, guided by World Skate criteria. Despite different competition formats, the judging criteria for both street and park disciplines are the same, developed on the values, principles, and virtues held within the skateboarding community. Given skating's recent Olympic debut, understanding what specifically constitutes success would seem paramount for skaters to target progression in the sport. To assess if the skateboarding community understands and aligns on judging competitive success criteria, and train accordingly, 33 skaters of various skill levels and disciplines completed a 35-question online survey. Participants included elite (i.e., sponsored, n=4), regional (New Zealand) amateur (n=10), and recreational (n=19) skaters. A mixed-methods, cross-sectional approach revealed that community perspectives on competitive and recreational performance generally aligned with World Skate judging criteria, emphasizing 'flow' and 'style'. Competitive skaters appeared to adjust their training accordingly, however, views on the scale and order of importance of judging criteria vary by involvement, skill level, and discipline, suggesting that an overall impression of skateboarding performance is highly individualistic and ambiguous. This likely leaves coaches and athletes speculating about what constitutes a winning performance and compromises targeted training. The survey's findings, though limited in their scope, emphasize the need for clarity in subjective judging criteria and application. Future research should implement objective explorations of street and park competitive skateboarding performances, respectively.

CHAPTER 4: DEVELOPMENT AND RELIABILITY OF A STREET SKATEBOARDING NOTATIONAL ANALYSIS FRAMEWORK AND APPLICATION

Notational analysis (NA) systems are regularly used to quantify sports performance but have not been adopted in competitive skateboarding. In this study, we aimed to develop an NA application to quantify outcome-related aspects of skateboarding judging criteria (trick selection, obstacle selection, and execution), leveraging known skatepark obstacles and trick classification from public broadcast footage (60 Hz) of the Tokyo 2020 Olympic Men's and Women's semi-finals. We also assessed the intra- and inter-rater reliability of frame selection for key trick attempt events: take-off, event (obstacle interaction) start and end, and landing. Frame selection from 593 trick attempts (male = 324, female = 269) were found reliable (mean absolute difference (MAD) < 3 frames) by a single, experienced rater. Take-off (MAD: intra-rater = 1.43, inter-rater = 3.82 frames) and landing frame (MAD: intra-rater = 1.33, inter-rater = 1.55 frames) were more reliably selected than obstacle interaction (MAD: Inter = 2.04–2.26, Inter = 3.62–4.35 frames), attributed to obstacle and trick type. Generally, trick attempts over longer durations appeared less reliable, but still within useable limits; as such, the NA approach used in this study could be used for describing and understanding performance in elite street skateboarding.

CHAPTER 5: SKATEBOARDING'S OLYMPIC DEBUT: A COMPARATIVE ANALYSIS OF THE MEN'S AND WOMEN'S STREET COMPETITION

The aim of this study was to describe aspects of performance in the Tokyo 2020 Olympic street skateboarding competition and compare male and female skaters. Trick attempts (TA=1118) were extracted from broadcast footage of the semi-finals and finals, using notational analysis. Descriptive analyses were adopted to characterise performance, with robust linear mixed-effects models comparing attempt scores (run [RUN] and best-trick [BT]) between the sexes. Male RUN (β=1.71 [1.43, 1.99]) and BT (β=1.85 [1.55, 2.15]) scores were higher and more variable than females. There was more trick variety during BTs, but less obstacle variability compared to RUNs. Skaters bailed a greater proportion of BT TAs (54.6% vs. 14.3% RUN TAs. Males demonstrated greater variety than females by diversifying take-off (28.2% vs. 3.3% non-regular, respectively) and landing (25.7% vs. 6.2% non-regular, respectively) stances, attempting more unique tricks (122 vs. 74, respectively), and using larger, feature obstacles (40.7% vs. 33.9% respectively). Alternatively, females demonstrated wider course use during BTs (32.1% vs. 15%, respectively), corresponding to less feature obstacle use; perhaps indicating a barrier to engagement due to developing physical qualities. Future research should explore men's and women's divisions separately to understand key factors for success.

CHATPER 6: SEND IT? PERFORMANCE INDICATORS OF THE TOKYO 2020 OLYMPIC STREET SKATEBOARDING HIGHLIGHT THE IMPORTANCE OF BALANCING RISK FOR COMPETITIVE SUCCESS

This study investigated the influence of performance variables on overall impression scores in competitive street skateboarding best-trick (BT) and run (RUN) attempts. Notational analysis was conducted on footage of trick attempts (TA) from the Tokyo 2020 Olympic men's and women's divisions to quantify aspects of trick and obstacle variety and difficulty, consistency, and originality according to judging criteria. Linear mixed-effects models were built for BT (n=125) and RUN (n=112) scores, with predictors being performance factors. Models for RUN (R_M^2: $Model_{RUN\text{-}M}$= 0.750, $Model_{RUN\text{-}W}$=0.829) were better fit than BT for both women and men (R_M^2: $Model_{BT\text{-}W}$=0.520, $Model_{BT\text{-}M}$=0.302), likely attributable to the exclusion of bailed BT TAs (153) thus limited sample size. In BT, males and females (β_W=0.86, p_W<0.001) who used feature obstacles tended to score better than those who did not. A positive relationship was found between combination tricks and BT scores for the men's competition (β_M=1.38, p_M<0.001); but flip tricks (β_W=1.10, p_W<0.001) and take-off stance, specifically fakie, was more impactful for women BTs (β_W=1.10, p_W=0.002). Up to a certain point in RUNs, male and female skaters who attempted more tricks (β_W=3.67, β_M=4.58, p<0.001) and bailed less (β_W=-0.39, β_M=-0.40, p<0.001) scored significantly higher, after which more TAs decreased scores (β_W=-2.00, β_M=-1.65, p<0.001). Overall, various factors appear related with performance, and might warrant attention in competition – like utilising feature obstacles, flipping the board, and leveraging novelty whilst balancing bail risk. Interaction effects, specifically between trick and obstacle measures, should be explored further to best support skaters as the sport and its athletes evolve.

Appendix III: Supplementary Material (Chapter 3)

SURVEY ADVERTISMENT

COPY OF SURVEY

Defining skateboarding performance success: A community perspective

Kia Ora!

My name is Shelley Diewald and I am a PhD student at Auckland University of Technology and I would like to invite you to participate in this study!

We are inviting you as you are either **a skateboarder**, **skateboard coach**, and/or a **skateboard judge**.

We want to find out your opinions about success in skateboarding! As a member of the skateboarding community, we are interested in what you believe is essential to be the best skateboarder, coach, and/or judge! This research is in collaboration with High Performance Sport New Zealand and the Sports Research Institute of New Zealand

This survey should take roughly 5 - 15 minutes to complete. It will remain open until 31 December 2023.

Participation in this research is entirely voluntary, and you can withdraw from the study at any time.

* Indicates required question

HIGH PERFORMANCE
SPORT NEW ZEALAND

skateboarding.nz

AUT SPORTS PERFORMANCE
RESEARCH INSTITUTE NEW ZEALAND

Ethical Consent Waiver

Completion of this survey indicates your consent:

Attached is a *link to an online information sheet*. Please take the time to read this information sheet to gain an understanding of what your participation in this survey includes.

After you have read the information sheet, if you would like to complete the survey, please answer the following question:

1. I have read the attached information sheet, and I agree to take part in this research *

   Mark only one oval.

   ⬭ Yes

Research Findings

2. Would you like a copy of the research findings in the form of a peer-reviewed journal article?

   Mark only one oval.

   ⬭ Yes *Skip to question 3*

   ⬭ No *Skip to question 3*

Demographics

3. How old are you? *

   Type in your age in years (e.g. "##") - No text please

   ____

4. Gender? *

Mark only one oval.

- ( ) Female
- ( ) Male
- ( ) Non-binary
- ( ) Prefer not to say
- ( ) Other: ____________________

5. Nationality *

Mark only one oval.

- Afghanistan
- Akrotiri
- Albania
- Algeria
- American Samoa
- Andorra
- Angola
- Anguilla
- Antarctica
- Antigua and Barbuda
- Argentina
- Armenia
- Aruba
- Ashmore and Cartier Islands
- Australia
- Austria
- Azerbaijan
- Bahamas, The
- Bahrain
- Bangladesh
- Barbados
- Bassas da India
- Belarus
- Belgium
- Belize
- Benin
- Bermuda
- Bhutan
- Bolivia
- Bosnia and Herzegovina
- Botswana

- Bouvet Island
- Brazil
- British Indian Ocean Territory
- British Virgin Islands
- Brunei
- Bulgaria
- Burkina Faso
- Burma
- Burundi
- Cambodia
- Cameroon
- Canada
- Cape Verde
- Cayman Islands
- Central African Republic
- Chad
- Chile
- China
- Christmas Island
- Clipperton Island
- Cocos (Keeling) Islands
- Colombia
- Comoros
- Congo, Democratic Republic of the
- Congo, Republic of the
- Cook Islands
- Coral Sea Islands
- Costa Rica
- Cote d'Ivoire
- Croatia
- Cuba
- Cyprus
- Czech Republic

- Denmark
- Dhekelia
- Djibouti
- Dominica
- Dominican Republic
- Ecuador
- Egypt
- El Salvador
- Equatorial Guinea
- Eritrea
- Estonia
- Ethiopia
- Europa Island
- Falkland Islands (Islas Malvinas)
- Faroe Islands
- Fiji
- Finland
- France
- French Guiana
- French Polynesia
- French Southern and Antarctic Lands
- Gabon
- Gambia, The
- Gaza Strip
- Georgia
- Germany
- Ghana
- Gibraltar
- Glorioso Islands
- Greece
- Greenland
- Grenada
- Guadeloupe

- Guam
- Guatemala
- Guernsey
- Guinea
- Guinea-Bissau
- Guyana
- Haiti
- Heard Island and McDonald Islands
- Holy See (Vatican City)
- Honduras
- Hong Kong
- Hungary
- Iceland
- India
- Indonesia
- Iran
- Iraq
- Ireland
- Isle of Man
- Israel
- Italy
- Jamaica
- Jan Mayen
- Japan
- Jersey
- Jordan
- Juan de Nova Island
- Kazakhstan
- Kenya
- Kiribati
- Korea, North
- Korea, South
- Kuwait

- Kyrgyzstan
- Laos
- Latvia
- Lebanon
- Lesotho
- Liberia
- Libya
- Liechtenstein
- Lithuania
- Luxembourg
- Macau
- Macedonia
- Madagascar
- Malawi
- Malaysia
- Maldives
- Mali
- Malta
- Marshall Islands
- Martinique
- Mauritania
- Mauritius
- Mayotte
- Mexico
- Micronesia, Federated States of
- Moldova
- Monaco
- Mongolia
- Montenegro
- Montserrat
- Morocco
- Mozambique
- Namibia

- Nauru
- Navassa Island
- Nepal
- Netherlands
- Netherlands Antilles
- New Caledonia
- New Zealand
- Nicaragua
- Niger
- Nigeria
- Niue
- Norfolk Island
- Northern Mariana Islands
- Norway
- Oman
- Pakistan
- Palau
- Panama
- Papua New Guinea
- Paracel Islands
- Paraguay
- Peru
- Philippines
- Pitcairn Islands
- Poland
- Portugal
- Puerto Rico
- Qatar
- Reunion
- Romania
- Russia
- Rwanda
- Saint Helena

- Saint Kitts and Nevis
- Saint Lucia
- Saint Pierre and Miquelon
- Saint Vincent and the Grenadines
- Samoa
- San Marino
- Sao Tome and Principe
- Saudi Arabia
- Senegal
- Serbia
- Seychelles
- Sierra Leone
- Singapore
- Slovakia
- Slovenia
- Solomon Islands
- Somalia
- South Africa
- South Georgia and the South Sandwich Islands
- Spain
- Spratly Islands
- Sri Lanka
- Sudan
- Suriname
- Svalbard
- Swaziland
- Sweden
- Switzerland
- Syria
- Taiwan
- Tajikistan
- Tanzania
- Thailand

- Timor-Leste
- Togo
- Tokelau
- Tonga
- Trinidad and Tobago
- Tromelin Island
- Tunisia
- Turkey
- Turkmenistan
- Turks and Caicos Islands
- Tuvalu
- Uganda
- Ukraine
- United Arab Emirates
- United Kingdom
- United States
- Uruguay
- Uzbekistan
- Vanuatu
- Venezuela
- Vietnam
- Virgin Islands
- Wake Island
- Wallis and Futuna
- West Bank
- Western Sahara
- Yemen
- Zambia
- Zimbabwe

6. Where do you currently live? *

Mark only one oval.

- Same as Nationality
- Afghanistan
- Akrotiri
- Albania
- Algeria
- American Samoa
- Andorra
- Angola
- Anguilla
- Antarctica
- Antigua and Barbuda
- Argentina
- Armenia
- Aruba
- Ashmore and Cartier Islands
- Australia
- Austria
- Azerbaijan
- Bahamas, The
- Bahrain
- Bangladesh
- Barbados
- Bassas da India
- Belarus
- Belgium
- Belize
- Benin
- Bermuda
- Bhutan
- Bolivia
- Bosnia and Herzegovina

- Botswana
- Bouvet Island
- Brazil
- British Indian Ocean Territory
- British Virgin Islands
- Brunei
- Bulgaria
- Burkina Faso
- Burma
- Burundi
- Cambodia
- Cameroon
- Canada
- Cape Verde
- Cayman Islands
- Central African Republic
- Chad
- Chile
- China
- Christmas Island
- Clipperton Island
- Cocos (Keeling) Islands
- Colombia
- Comoros
- Congo, Democratic Republic of the
- Congo, Republic of the
- Cook Islands
- Coral Sea Islands
- Costa Rica
- Cote d'Ivoire
- Croatia
- Cuba
- Cyprus

- Czech Republic
- Denmark
- Dhekelia
- Djibouti
- Dominica
- Dominican Republic
- Ecuador
- Egypt
- El Salvador
- Equatorial Guinea
- Eritrea
- Estonia
- Ethiopia
- Europa Island
- Falkland Islands (Islas Malvinas)
- Faroe Islands
- Fiji
- Finland
- France
- French Guiana
- French Polynesia
- French Southern and Antarctic Lands
- Gabon
- Gambia, The
- Gaza Strip
- Georgia
- Germany
- Ghana
- Gibraltar
- Glorioso Islands
- Greece
- Greenland
- Grenada

- Guadeloupe
- Guam
- Guatemala
- Guernsey
- Guinea
- Guinea-Bissau
- Guyana
- Haiti
- Heard Island and McDonald Islands
- Holy See (Vatican City)
- Honduras
- Hong Kong
- Hungary
- Iceland
- India
- Indonesia
- Iran
- Iraq
- Ireland
- Isle of Man
- Israel
- Italy
- Jamaica
- Jan Mayen
- Japan
- Jersey
- Jordan
- Juan de Nova Island
- Kazakhstan
- Kenya
- Kiribati
- Korea, North
- Korea, South

- Kuwait
- Kyrgyzstan
- Laos
- Latvia
- Lebanon
- Lesotho
- Liberia
- Libya
- Liechtenstein
- Lithuania
- Luxembourg
- Macau
- Macedonia
- Madagascar
- Malawi
- Malaysia
- Maldives
- Mali
- Malta
- Marshall Islands
- Martinique
- Mauritania
- Mauritius
- Mayotte
- Mexico
- Micronesia, Federated States of
- Moldova
- Monaco
- Mongolia
- Montenegro
- Montserrat
- Morocco
- Mozambique

- Namibia
- Nauru
- Navassa Island
- Nepal
- Netherlands
- Netherlands Antilles
- New Caledonia
- New Zealand
- Nicaragua
- Niger
- Nigeria
- Niue
- Norfolk Island
- Northern Mariana Islands
- Norway
- Oman
- Pakistan
- Palau
- Panama
- Papua New Guinea
- Paracel Islands
- Paraguay
- Peru
- Philippines
- Pitcairn Islands
- Poland
- Portugal
- Puerto Rico
- Qatar
- Reunion
- Romania
- Russia
- Rwanda

- Saint Helena
- Saint Kitts and Nevis
- Saint Lucia
- Saint Pierre and Miquelon
- Saint Vincent and the Grenadines
- Samoa
- San Marino
- Sao Tome and Principe
- Saudi Arabia
- Senegal
- Serbia
- Seychelles
- Sierra Leone
- Singapore
- Slovakia
- Slovenia
- Solomon Islands
- Somalia
- South Africa
- South Georgia and the South Sandwich Islands
- Spain
- Spratly Islands
- Sri Lanka
- Sudan
- Suriname
- Svalbard
- Swaziland
- Sweden
- Switzerland
- Syria
- Taiwan
- Tajikistan
- Tanzania

- Thailand
- Timor-Leste
- Togo
- Tokelau
- Tonga
- Trinidad and Tobago
- Tromelin Island
- Tunisia
- Turkey
- Turkmenistan
- Turks and Caicos Islands
- Tuvalu
- Uganda
- Ukraine
- United Arab Emirates
- United Kingdom
- United States
- Uruguay
- Uzbekistan
- Vanuatu
- Venezuela
- Vietnam
- Virgin Islands
- Wake Island
- Wallis and Futuna
- West Bank
- Western Sahara
- Yemen
- Zambia
- Zimbabwe

7. Which **BEST** describes your **current** skateboarding community involvement? *
(*Select only 1)*

- **Skateboarder:** Actively skateboarding at least 1x / week *(unless currently injured)*
- **Coach:** Actively coaching skateboarders in any area
- **Judge:** Actively judging skateboarding competitions

Mark only one oval.

- Skateboarder *Skip to question 8*
- Coach *Skip to question 43*
- Judge *Skip to question 52*

Skip to question 61

SKATEBOARDER

8. Preferred Stance?

Mark only one oval.

- Regular
- Goofy

9. How many years have you been actively skateboarding?

At least 1x per week

10. How much are you **currently** skateboarding?

Select only 1 answer

Mark only one oval.

- Multiple times per day (more than 60 minutes / day)
- Every day (more than 30 minutes / day)
- A few times per week
- A few times per month
- A handful of times per year
- Currently Injured and not skating

11. Are you actively competing in skateboarding competitions **OR** intend to compete in next 12 months (at any level) *

Mark only one oval.

- Yes *Skip to question 16*
- No *Skip to question 24*

12. Have you **ever** had a coach for skateboarding?

Mark only one oval.

- Yes
- No

13. Have you ever *(currently or in the past)* had any assistance in improving your skateboarding?

Select all that apply

Check all that apply.

- [ ] Technical (Skill coach)
- [ ] Physical Coach / Personal Trainer / Physiotherapist
- [ ] Competition (Manager)
- [ ] Mental Skills Coach
- [ ] Peers
- [ ] Other: __________

14. What is your **current** WorldSkate ranking?

Type "0" if not currently ranked

____

15. What is your **highest ever achieved** WorldSkate ranking?

Type "0" if not currently ranked

____

SKATEBOARDER - Competition History

16. What skateboarding discipline do you normally compete in?

Select all that apply

Check all that apply.

- [ ] Street
- [ ] Park
- [ ] Vert
- [ ] Other: __________

17. What is the **highest level** you have competed at?

Mark only one oval.

- Never Competed
- Regional
- National
- Continental
- International
- Olympics

18. How many skateboarding competitions have you competed in?

Mark only one oval.

- Never Competed
- 1
- 1 - 5
- 6 - 10
- 10 - 20
- 20+

19. How many skateboarding competitions have you competed in **so far in the past year**?

Mark only one oval.

- None
- 1
- 1 - 5
- 6 - 10
- 10 - 20
- 20+

20. When was your **first ever** skateboarding competition?

Type in the year (i.e. 1998, 2021)

21. Do you plan your runs / tricks before the competition?

Mark only one oval.

- Yes
- No
- Sometimes

22. Do you bring a coach/manager with you to skateboarding competitions?

Mark only one oval.

- Yes *Skip to question 23*
- No *Skip to question 24*
- Sometimes *Skip to question 23*

Skip to question 24

SKATEBOARDER - Coaches and Competition

23. Does your coach assist with run / trick planning?

Mark only one oval.

- Yes
- No

Skip to question 24

Preferred Skateboarding Style

24. What is your preferred skateboarding discipline?

You will be asked to answer the following questions based on this discipline.

Mark only one oval.

- Street *Skip to question 25*
- Park *Skip to question 61*
- Vert *Skip to question 61*

STREET SKATEBOARDER - Technical Skill Level (OPTIONAL SECTION)

You indicated you prefer street skating. This sectional is **optional** and will take an additional 5-10 minutes. You will be asked about your specific technical ability.

- What tricks have you attempted?
- What tricks can you land?
- How consistent are you landing tricks?

25. If you do not want to complete, please select **SKIP THIS SECTION** below

Mark only one oval.

- SKIP THIS SECTION *Skip to question 61*
- CONTINUE *Skip to question 26*

SKATEBOARDER - Technical Skill Level

26. Are you comfortable doing the following?

Mark only one oval per row.

	Yes	Somewhat	No
Riding (rolling, kick turns, slides, etc.)			
Fundamentals (ollie, 180 ollie, etc.)			
Flip Tricks (kickflip, heelflip, tre-flip, etc.)			
Grind and Slide Tricks			
Combination Tricks (Flip-in/out)			
Airs, grabs, and stalls			

27. Are you comfortable riding switch?

Mark only one oval per row.

	Yes	Somewhat	No
Riding (rolling, kick turns, slides, etc.)	⬭	⬭	⬭
Fundamentals (ollie, 180 ollie, etc.)	⬭	⬭	⬭
Flip Tricks (kickflip, heelflip, tre-flip, etc.)	⬭	⬭	⬭
Grind and Slide Tricks	⬭	⬭	⬭
Combination Tricks (Flip-in/out)	⬭	⬭	⬭
Airs, grabs, and stalls	⬭	⬭	⬭

28. What is your "**go-to**" trick for a best-trick attempt at a competition?

____

Fundamental Tricks

Skill Level Options:

- Don't know what this is
- Never attempted
- Currently learning
- Landing, but not consistently
- On lock (mastered)

29. **Fundamental Tricks**

Please complete based on your current skateboarding ability

Mark only one oval per row.

	Don't know what this is	Never attempted	Currently learning	Landing, but not consistently	On lock (Mastered)
Ollie					
Fakie Ollie					
Backside 180 ollie					
Frontside 180 ollie					
Backside Half Cab					
Frontside Half Cab					
Backside 360 ollie					
Frontside 360 ollie					
Backside Caballerial					
Frontside Caballerial					
Nollie					
Nollie Backside 180					
Nollie Frontside 180					
Nollie Backside					

360					
Nollie Frontside 360	◯	◯	◯	◯	◯

30. If any tricks were missing from the list, please add them here:

Please separate trick names with a colon (e.g. ollie: kickflip: hurricane)

Technical Skill Level - Attempted Grind and Slide Tricks

31. Have you ever attempted **ANY grind or slide** tricks?

Mark only one oval.

◯ Yes *Skip to question 32*

◯ No *Skip to question 34*

Grind and Slide Tricks

Skill Level Options:

- Don't know what this is
- Never attempted
- Currently learning
- Landing, but not consistently
- On lock (mastered)

32. **Grind and Slide Tricks**

Please complete based on your current skateboarding ability

Mark only one oval per row.

	Don't what this is	Never attempted	Currently learning	Landing, but not consistently	On lock (Mastered)
Backside Boardslide					
Backside Noseslide					
Backside 50-50 grind					
Backside 5-0 grind					
Backside Feeble grind					
Backside Tailslide					
Backside Lipslide					
Backside Smith grind					
Backside Nosegrind					
Backside Crooked grind					
Backside Overcrook					
Backside Hurricane Grind					

Backside Sugarcane Grind					
Backside Bluntslide					
Backside Noseblunt Slide					
Frontside Boardslide					
Frontside Noseslide					
Frontside 50-50 grind					
Frontside 5-0 grind					
Frontside Feeble grind					
Frontside Tailslide					
Frontside Lipslide					
Frontside Smith grind					
Frontside Nosegrind					
Frontside Crooked grind					
Frontside Overcrook					
Frontside Hurricane					

Grind

Frontside Hurricane Grind					
Frontside Sugarcane Grind					
Frontside Bluntslide					
Frontside Noseblunt Slide					
Fakie Backside Noseslide					
Fakie Backside 50-50 Grind					
Fakie Backside 5-0 Grind					
Fakie Backside Crooked Grind					
Fakie Backside Nosegrind					
Fakie Backside Tailslide					
Fakie Frontside Noseslide					
Fakie Frontside 50-50 Grind					

Fakie
Frontside

Frontside 50-50 Grind / Frontside 5-0 Grind					
Fakie Frontside 5-0 Grind	◯	◯	◯	◯	◯
Fakie Frontside Crooked Grind	◯	◯	◯	◯	◯
Fakie Frontside Nosegrind	◯	◯	◯	◯	◯
Fakie Frontside Tailslide	◯	◯	◯	◯	◯
Casper Slide	◯	◯	◯	◯	◯
Darkslide	◯	◯	◯	◯	◯
Suski Grind	◯	◯	◯	◯	◯
Howard Grind	◯	◯	◯	◯	◯

33. If any tricks were missing from the list, please add them here:

Please separate trick names with a colon (e.g. ollie: kickflip: hurricane)

Technical Skill Level - Attempted Flip Tricks

34. Have you ever attempted **<u>ANY</u> flip** skateboarding tricks?

Mark only one oval.

- Yes *Skip to question 35*
- No *Skip to question 37*

Flip Tricks

Skill Level Options:

- Don't know what this is
- Never attempted
- Currently learning
- Landing, but not consistently
- On lock (mastered)

35. **Flip Tricks**

Please complete based on your current skateboarding ability

Mark only one oval per row.

	Don't know what this is	Never attempted	Currently learning	Landing, but not consistently	On lock (Mastered)
Kickflip	⬭	⬭	⬭	⬭	⬭
Heeflip	⬭	⬭	⬭	⬭	⬭
Backside 180 shuvit	⬭	⬭	⬭	⬭	⬭
Frontside 180 shuvit	⬭	⬭	⬭	⬭	⬭
Backside Shuvit Kickflip	⬭	⬭	⬭	⬭	⬭
Frontside Shuvit Heelflip	⬭	⬭	⬭	⬭	⬭
Backside 360 Shuvit	⬭	⬭	⬭	⬭	⬭
Backside 360 Pop Shuvit	⬭	⬭	⬭	⬭	⬭
Frontside 360 Pop Shuvit	⬭	⬭	⬭	⬭	⬭
360 Flip	⬭	⬭	⬭	⬭	⬭
Hardflip	⬭	⬭	⬭	⬭	⬭
Inward Heelflip	⬭	⬭	⬭	⬭	⬭
Double Kickflip	⬭	⬭	⬭	⬭	⬭
Double					

Heelflip
Double
Heelflip
Backside
180
Backside
Kickflip
180
Kickflip
Backside
180
Backside
Heelflip
180
Heelflip
Frontside
180
Frontside
Kickflip
180
Kickflip
Frontside
180
Frontside
Heelflip
180
Heelflip
Backside
360
Backside
Kickflip
360
Kickflip
Casper
Flip
Casper
Flip
Hospital
Flip
Hospital
Flip
Ollie
Impossible
Ollie
Impossible
Laser Flip
Laser Flip
Triple
Kickflip
Triple
Kickflip
Underflip
Underflip
Backside
Bigspin
Backside
Bigspin
Fronside
Bigspin
Fronside
Bigspin
Backside
Biggerspin
Backside
Biggerspin
Frontside
Biggerspin

Backside
Frontside
Kickflip
Biggerspin
Bigspin

Backside
Frontside
Kickflip
Heelflip
Bigspin
Bigspin

Frontside
Backside
Heelflip
Biggerflip
Bigspin

Fakie
Backside
Kickflip
Biggerflip

Fakie
Fakie
Heelflip
Kickflip

Fakie
Fakie
Backside
Heelflip
180 Pop

Shuvit
Fakie

Backside
Fakie
180 Pop
Frontside
Shuvit
180 Pop

Shuvit
Fakie

Frontside
Fakie 360
180 Pop
Flip
Shuvit

Fakie
Fakie 360
Hardflip
Flip

Fakie
Fakie
Inward
Hardflip
Heelflip

Fakie
Fakie
Inward
Shuvit
Heelflip
Kickflip

Fakie
Fakie
Shuvit
Shuvit
Kickflip
Heelflip

Fakie
Fakie
Shuvit
Backside
Heelflip
Bigspin

Fakie

Fakie Frontside Bigspin					
Fakie Backside Bigspin					
Fakie Backside Biggerspin					
Fakie Frontside Biggerspin					
Fakie Backside Kickflip Bigspin					
Fakie Frontside Biggerspin					
Fakie Frontside Heelflip Bigspin (Rick Flip)					
Fakie Backside Kickflip Bigspin					
Fakie Frontside Heelflip Bigspin (Rick Flip)					
Fakie Backside Biggerflip					
Fakie Ollie Impossible					
Fakie Backside Biggerflip					
Front Foot Impossible					
Fakie Ollie Impossible					
Half Cab Kickflip					
Front Foot Impossible					
Half Cab Heelflip					
Half Cab Kickflip					
Caballerial Kickflip					
Half Cab Heelflip					
Caballerial Heelflip					
Caballerial Kickflip					
Frontside Half Cab Kickflip					
Caballerial Heelflip					
Frontside Half Cab					

Half Cab
Frontside
Heelflip
Half Cab
Nollie
Kickflip
Kickflip
Frontside
Nollie
Half Cab
Heelflip
Heelflip
Nollie
Nollie
Kickflip
Backside
180 Shuvit
Nollie
Nollie
Heelflip
Frontside
Nollie
180 Shuvit
Backside
Nollie 360
180 Shuvit
Flip
Nollie
Nollie
Frontside
180 Shuvit
Hardflip
Nollie
Nollie 360
Flip
Inward
Heelflip
Nollie
Nollie
Hardflip
Shuvit
Nollie
Kickflip
Inward
Nollie
Heelflip
Shuvit
Nollie
Heelflip
Shuvit
Nollie
Kickflip
Backside
Nollie
Bigspin
Shuvit
Nollie
Heelflip
Frontside
Nollie
Bigspin
Backside
Nollie
Bigspin
Backside
Nollie
180
Frontside
Kickflip
Bigspin
Nollie
Backside

180
Nollie
Heelflip
Backside

180
Nollie Cab
Kickflip
Kickflip

Nollie
Nollie Cab
Backside
Heelflip
180

Heelflip
Nollie

Frontside
Nollie Cab
180
Kickflip
Kickflip

Nollie Cab
Nollie
Heelflip
Frontside

180
Nollie
Heelflip
Frontside

180
No
Kickflip
Comply

(Straight)
Nollie

Frontside
Frontside
180
180 No
Heelflip
Comply

No
Backside
Comply
180 No
(Straight)
Comply

Frontside
Frontside
180 No
360 No
Comply
Comply

Backside
Backside
180 No
360 No
Comply
Comply

Frontside
43 Shifty
360 No
(Frontside
Comply
No

Comply
Backside
Revert)
360 No

Comply
Backside

43 Shifty
43 Shifty

(Frontside

No

Comply Revert)					
Backside 43 Shifty	⬭	⬭	⬭	⬭	⬭

36. If any tricks were missing from the list, please add them here:

Please separate trick names with a colon (e.g. ollie: kickflip: hurricane)

Technical Skill Level - Attempted Stall Tricks

37. Have you ever attempted **ANY air/grab/stall** skateboarding tricks?

Mark only one oval.

⬭ Yes *Skip to question 38*

⬭ No *Skip to question 42*

Stalls

Skill Level Options:

- Don't know what this is
- Never attempted
- Currently learning
- Landing, but not consistently
- On lock (mastered)

38. **Stalls**

Please complete based on your current skateboarding ability

Mark only one oval per row.

	Don't know what this is	Never attempted	Currently learning	Landing, but not consistently	On lock (Mastered)
Backside 50-50 Stall					
Frontside 50-50 Stall					
Backside Feeble Stall					
Frontside Feeble Stall					
Backside 5-0 Stall					
Frontside 5-0 Stall					
Backside Disaster					
Frontside Disaster					
Backside Tail Stall					
Frontside Tail Stall					
Backside Crooked Stall					
Frontside Crooked Stall					

Backside Smith Stall					
Frontside Smith Stall					
Backside Rock 'n' Roll					
Frontside Rock 'n' Roll					
Backside Hurricane Stall					
Frontside Hurricane Stall					
Backside Sugarcane					
Frontside Sugarcane					
Pull-in Blunt to Fakie					
Blunt to Fakie					
Backside Blunt					
Frontside Blunt					
Backside Noseblunt					
Frontside Noseblunt					
Fakie					

Noseblunt Fakie					
Noseblunt Backside					
Nose Pick Backside					
Nose Pick Frontside					
Rock to Fakie					
Fakie Hang-up					
Fakie Tail Stall					
Nose Stall to Fakie					

39. If any tricks were missing from the list, please add them here.

Please separate trick names with a colon (e.g. ollie: kickflip: hurricane)

Technical Skill Level - Attempted Combination Tricks

40. Have you ever attempted **ANY combination** skateboarding tricks?

Mark only one oval.

- Yes *Skip to question 40*
- No *Skip to question 42*

Combination Tricks

Skill Level Options:

- Don't know what this is
- Never attempted
- Currently learning
- Landing, but not consistently
- On lock (mastered)

41. Please complete based on your current skateboarding ability

Mark only one oval per row.

	Don't know what this is	Never attempted	Currently learning	Landing, but not consistently	On lock (mastered)
Flip-in to Grind					
Shuvit-in to Grind					
Bigspin-in to Grind					
Grind to Flip-out					
Grind to Shuvit-out					
Grind to Bigspin-out					
Flip-in to Slide					
Shuvit-in to Slide					
Bigspin-in to Slide					
Slide to Flip-out					
Slide to Shuvit-out					
Slide to					

Bigspin-Slide to Bigspin-out					
Flip-in to Grind to Flip-out					
Flip-in to Grind to Shuvit-out					
Flip-in to Grind to Bigspin-out					
Shuvit-in to Grind to Flip-out					
Shuvit-in to Grind to Shuvit-out					
Shuvit-in to Grind to Bigspin-out					
Bigspin-in to Grind to Flip-out					
Bigspin-in to Grind to Shuvit-out					
Bigspin-in to					

Grind to Bigspin-out

Bigspin-in to Grind to Bigspin-out					
Flip-in to Slide to Flip-out					
Flip-in to Slide to Shuvit-out					
Flip-in to Slide to Bigspin-out					
Shuvit-in to Slide to Flip-out					
Shuvit-in to Slide to Shuvit-out					
Shuvit-in to Slide to Bigspin-out					
Bigspin-in to Slide to Flip-out					
Bigspin-in to Slide to Shuvit-out					

Bigspin-

Bigspin-Shuvit-in to out					
Slide to Bigspin-out Bigspin-in to					
Slide to Bigspin-out	◯	◯	◯	◯	◯

Technical Skill - Obstacles

Comfort Level Options:

- Not comfortable at all
- Somewhat uncomfortable (attempted tricks before)
- Neutral (never tried)
- Somewhat comfortable (general riding and trick attempts)
- Extremely comfortable (difficult flip and grind tricks)

42. Please describe your **current** comfort level skating and performing tricks on the following obstacles

Mark only one oval per row.

	Not comfortable at all	Somewhat uncomfortable (attempted tricks before)	Neutral (never tried)	Somewhat comfortable (general riding and trick attempts)	Extremely comfortabl (difficult fli and grind tricks)
Flat ground	◯	◯	◯	◯	◯
Inclines/declines/banks	◯	◯	◯	◯	◯
Gaps	◯	◯	◯	◯	◯
Hips	◯	◯	◯	◯	◯
Ledges / Hubba	◯	◯	◯	◯	◯
Stairs (1-4 steps)	◯	◯	◯	◯	◯
Stairs (4+ steps)	◯	◯	◯	◯	◯
Square rails (flat)	◯	◯	◯	◯	◯
Round rails (flat)	◯	◯	◯	◯	◯
Square rails (incline)	◯	◯	◯	◯	◯
Round rails (incline)	◯	◯	◯	◯	◯
Mini-ramps	◯	◯	◯	◯	◯
Quarterpipes	◯	◯	◯	◯	◯
Vert ramps (>8 feet)	◯	◯	◯	◯	◯
Bowls	◯	◯	◯	◯	◯

Skip to question 61

COACH

Details for "Coach"

43. What **best** describes the type of coaching you provide skateboarders?

*Select **1 answer** that applies best to most of your coaching*

Mark only one oval.

- Technical (Skill)
- Physical Coach / Personal Trainer / Physiotherapist
- Tactical (Competition)
- Mental Skills
- Other: ____________

44. How many athletes ***(in total)*** are you currently coaching?

____

45. Is coaching a "full-time" profession for you?

"Full-time" profession: You rely only on coaching as means of providing an income. Coaching is not voluntary and athletes are paying for your services

Mark only one oval.

- Yes
- No

46. How many years have you been ***actively*** coaching?

With at least 1 athlete

____

47. What age are ***most*** of your athletes?

Select only 1 answer

Mark only one oval.

- 0 - 9 years
- 10 - 15 years
- 16 - 20 years
- 21 - 29 years
- 30+ years

48. How do you train your athletes?

Select all that apply

Check all that apply.

- In-person
- Online
- Other: ____________________

49. What is the technical skill level of the athletes you coach?

Select all that apply

Check all that apply.

- Recreational
- Regionally Competitive
- Nationally Competitive
- Continentally Competitive
- Internationally Competitive
- Elite (Top 50 WorldSkate ranking)

50. What skateboarding discipline do your athletes compete in?

Select all that apply

Check all that apply.

- [ ] Street
- [ ] Park
- [ ] Vert
- [ ] Other: ____________________

51. Have you had any formal **or** informal coach training/certification?

Mark only one oval.

( ) Yes *Skip to question 59*

( ) No *Skip to question 61*

Skip to question 61

JUDGE

Details for "Judge"

52. How many skateboarding competitions have you judged in your career?

Mark only one oval.

( ) 0 - preparing for my first

( ) 1

( ) 2 - 5

( ) 6 - 10

( ) 10 - 20

( ) 20+

53. What is the **most recent** skateboarding competition you judged?

____

54. What competition level(s) have you judged?

Select all that apply

Check all that apply.

- [ ] Recreational
- [ ] Regional
- [ ] National
- [ ] Continental
- [ ] International
- [ ] WorldSkate sanctioned events

55. What age are ***most*** of the athletes in the competitions you are judging?

Select all that apply

Check all that apply.

- [ ] 0 - 9 years
- [ ] 10 - 15 years
- [ ] 16 - 20 years
- [ ] 21 - 29 years
- [ ] 30+ years

56. What technical skill level are ***most*** of the athletes you judge?

Select all that apply

Check all that apply.

- [ ] Recreational
- [ ] Regionally Competitive
- [ ] Nationally Competitive
- [ ] Continentally Competitive
- [ ] Internationally Competitive
- [ ] Elite (Top 100 WorldSkate ranking)

57. Have you completed the WorldSkate judging course?

THE FUNDAMENTALS OF SKATEBOARD JUDGING

Mark only one oval.

- Yes
- No
- In progress
- No, but I will now that I have this link!

58. Have you had any formal **or** informal judge training/certification?

Mark only one oval.

- Yes *Skip to question 59*
- No *Skip to question 61*

Skip to question 61

Formal / Informal Training / Certification

For skateboarding coaches and judges

59. Please describe your **formal** training / certification / qualifications:

60. Please describe your **informal** training / certification / qualifications:

Skip to question 61

Performance Success

61. What does success in skateboarding look like to you?

Select all that apply

Check all that apply.

- [ ] Winning competitions
- [ ] Representing my country at the Olympics
- [ ] Medaling at the Olympics
- [ ] Landing "NBD" tricks
- [ ] Having the most social media followers
- [ ] Sponsorships (Professional Career)
- [ ] Lifelong community involvement
- [ ] Peer Approval
- [ ] Progression
- [ ] Video Parts or Photos
- [ ] Other: ______________________

62. Rank these factors of importance for **competitive** skateboarding performance (as according to you personally)

*Please select importance for success **in competitions only** (not recreational)*

Mark only one oval per row.

	Not at all important	Low importance	Neutral	Important	Very Important
Difficulty of Tricks					
Variety of Tricks					
Difficulty of obstacles					
Variety of obstacles					
Originality of Tricks					
Quality of trick start (i.e. "pop")					
Quality of trick landing ("bolts")					
Style					
Fluidity of trick					
Power					
Aggression					
Aesthetics					
Speed					
Height					

Distance

Distance (grind time, air time, etc.)	◯	◯	◯	◯	◯
Number of tricks performed (i.e. during a run)	◯	◯	◯	◯	◯
Number of obstacles used (i.e. during a run)	◯	◯	◯	◯	◯
Linking of tricks (i.e. during a run)	◯	◯	◯	◯	◯
Flow	◯	◯	◯	◯	◯

63. Of all the factors above, which is the ***most important*** for **competitive** skateboarding performance?

*What do you think is the most important thing to being the best **competitive** skateboarder?*

Mark only one oval.

- Difficulty of Tricks
- Variety of Tricks
- Difficult of Obstacles
- Variety of Obstacles
- Originality of Trick
- Quality of trick start (i.e. "pop")
- Quality of trick landing ("bolts")
- Style
- Fluidity of Trick
- Power
- Aggression
- Speed
- Height
- Distance (grind time, air time, etc.)
- Number of tricks performed (i.e. during a run)
- Number of obstacles used (i.e. during a run)
- Linking of tricks (i.e. during a run)
- Flow

64. Do your answers to the above questions differ for **recreational** skateboarding (i.e. skateboarding for fun)?

Are any factors more/less important for competition than for recreational/fun?

Mark only one oval.

- No - my answers stay the same for both competitive and recreational skateboarding *Skip to question 67*
- Yes - I think skating for fun is different than competitive skateboarding *Skip to question 65*

Recreational Skateboarding Performance

If different from above (competitive)

65. Rank these factors of importance for **recreational** skateboarding performance (as according to you personally)

Mark only one oval per row.

	Not at all important	Low importance	Neutral	Important	Very Important
Difficulty of Tricks					
Variety of Tricks					
Difficulty of obstacles					
Variety of obstacles					
Originality of Tricks					
Quality of trick start (i.e. "pop")					
Quality of trick landing ("bolts"					
Style					
Fluidity of trick					
Power					
Aggression					
Aesthetics					
Speed					
Height					
Distance (grind time,					

air time, etc.)					
Number of tricks performed (i.e. during a run)					
Number of obstacles used (i.e. during a run)					
Linking of tricks (i.e. during a run)					
Flow					

66. Of all the factors above, which is the ***most important*** for **recreational** skateboarding performance?

What do you think is the most important thing to being the best skateboarder?

Mark only one oval.

- Difficulty of Tricks
- Variety of Tricks
- Difficult of Obstacles
- Variety of Obstacles
- Originality of Trick
- Quality of trick start (i.e. "pop")
- Quality of trick landing ("bolts")
- Style
- Fluidity of Trick
- Power
- Aggression
- Speed
- Height
- Distance (grind time, air time, etc.)
- Number of tricks performed (i.e. during a run)
- Number of obstacles used (i.e. during a run)
- Linking of tricks (i.e. during a run)
- Flow

Skip to question 67

Training for Competition

67. **For Skateboarders:** Which of these factors do you focus on when training to improve your skateboarding performance?

For Judges/Coaches: Which of these factors do you think skateboarders should focus on when training to improve **competitive** skateboarding performance?

Check all that apply.

	Select all that apply
Difficulty of Tricks	☐
Variety of Tricks	☐
Difficulty of obstacles	☐
Variety of obstacles	☐
Originality of Tricks	☐
Quality of trick start (i.e. "pop")	☐
Quality of trick landing ("bolts")	☐
Style	☐
Fluidity of trick	☐
Power	☐
Aggression	☐
Aesthetics	☐
Speed	☐

Height	☐
Distance (grind time, air time, etc.)	☐
Number of tricks performed (i.e. during a run)	☐
Number of obstacles used (i.e. during a run)	☐
Linking of tricks (i.e. during a run)	☐
Flow	☐
Other	☐

68. Are there any other factors not listed above?

Technology and Training Tools

69. Do you use **any technology** to help your skateboarding, judging, or coaching?

Technology *can be* ***any tool*** *(electronic or not) that you use to assist your skateboarding, coaching, and/or judging (i.e. GoPro, iPhone, apple watch, google sheets, GPS, etc.)*

Mark only one oval.

- Yes *Skip to question 70*
- No *Skip to question 76*

Skip to question 70

Technology

70. How often do you use the following technologies for your skateboarding, coaching, or judging?

Technology is ***any tool*** *(electronic or not) that you use to assist your skateboarding, coaching, and/or judging*

Mark only one oval per row.

	Never	Rarely	Occasionally	Weekly	Daily
Video Recording via Phone	⬭	⬭	⬭	⬭	⬭
Video Recording via GoPro (or similar)	⬭	⬭	⬭	⬭	⬭
Social Media (Instagram, Facebook, Twitter)	⬭	⬭	⬭	⬭	⬭
YouTube	⬭	⬭	⬭	⬭	⬭
GPS	⬭	⬭	⬭	⬭	⬭
Apple Watch, Fitbit (or similar)	⬭	⬭	⬭	⬭	⬭
Performance Analysis Software	⬭	⬭	⬭	⬭	⬭
Coaching Apps	⬭	⬭	⬭	⬭	⬭
Written /Typed Notes	⬭	⬭	⬭	⬭	⬭
Other	⬭	⬭	⬭	⬭	⬭

71. How important is the use of technology for your skating/coaching/judging?

Mark only one oval.

Not important at all

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Extremely important

72. How important are interpersonal skills (relationships) to your skating/coaching/judging?

Mark only one oval.

Not important at all

1 ⬭

2 ⬭

3 ⬭

4 ⬭

5 ⬭

Extremely Important

73. Other?

Leave blank if you don't use any other technologies

74. Do you currently use **any information** to inform and guide your training and/or performance?

Technologies, associated metrics, etc.

Mark only one oval.

- Yes *Skip to question 75*
- No *Skip to question 76*

Skip to question 76

Short Answer - Metrics

75. Please describe how you use technology and any metrics to inform and guide your training and/or performance

Metrics

76. What interest do you have in the following information?

Mark only one oval per row.

	Not interested at all	Would be great to see but would NOT use it	Neutral	Might use this	Would definitely use this information
How much are you skating?	◯	◯	◯	◯	◯
Identifying and tracking sessions (# of tricks, trick names, repetitions, bails, etc.)	◯	◯	◯	◯	◯
Trick performance / comparison with previous attempts	◯	◯	◯	◯	◯
Trick performance / comparison with peers	◯	◯	◯	◯	◯
Trick performance / comparison with professionals	◯	◯	◯	◯	◯
Distance / Length (air time, grind time, etc)	◯	◯	◯	◯	◯
Obstacle Height (3 stair vs. 10	◯	◯	◯	◯	◯

stair) vs. 10 stair)					
Speed (movement, into and out of tricks, body rotation)					
Style (in terms of timing e.g. catching a flip trick)					
Impacts when you land / bail a trick					
Time on board during a session					
Heart Rate					
Calories burned					
Sleep metrics					
Technique guidance					

Thank you!

Thank you for participating in this survey. We appreciate your time and responses.

Please take the time to complete the following feedback section to help us with our survey!

After all survey responses have been collected, [the results of the survey will be posted here:]

Survey Feedback

Any feedback you have would be greatly appreciated. Please complete the following questions to help refine this survey to best support the skateboarding community.

77. Please comment on the overall experience of completing the survey:

78. Please comment on the overall time it took to complete the survey:

79. Please comment on the wording of the questions. Do you feel any questions were hard to understand? If so, please be specific.

80. Do you feel this survey best collects the necessary information from the skateboarding community?

81. Please comment on the overall flow of the survey:

82. Any additional feedback?

The End.