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ORIGINAL ARTICLE

The influence of sub-technique and skiing velocity on air drag in skating style cross-country skiing

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Abstract

In cross-country skiing, velocities range from 2 m s^{-1} up to more than 20 m s^{-1} across undulating terrain, and aerodynamics can, therefore, make a large impact on performance. The aim of this study was to investigate the influence of skiing velocity on air drag for skating sub-techniques and downhill postures (tuck). Dynamic and static drag measurements for two athletes were performed in a wind tunnel in relevant velocity ranges for each sub-technique. The drag area decreased with velocity from 2 m s^{-1} to around 10–12 m s^{-1}, where it plateaued. No difference in air drag was found between the sub-techniques performed in upright postures (G2–G4) and thereby relatively similar frontal areas. In the G5 sub-technique performed without poling action in a lower posture, the reduced air drag was approximately 28% lower than for G2–G4 at similar velocities, and could even be reduced by an additional 21.7% by keeping the arms tucked in front of the body. In the downhill tucked postures, athletes could reduce air drag by 23% by keeping a low tuck, compared to a high tuck with straight legs. The sub-techniques were tested both dynamically and by averaging the static positions throughout the movements. The air drag was on average 6.1% lower for dynamic movements, indicating that dynamical movements like in cross-country skiing should be tested dynamically when evaluating air drag. Finally, the chosen cycle rate had minimal influence on air drag.

Keyword Cross-country skiing, Sub-technique, Air drag, Wind tunnel

1 Introduction

Cross-country (XC) skiing, biathlon and Nordic combined are Olympic winter sports employing the skating technique, which includes several sub-techniques optimized for different speed-incline combinations [1]. Within all these sub-techniques, the skiers must overcome gravitational, frictional and aerodynamic forces while skiing across hilly terrain. When skating, skiers use four main sub-techniques, so-called gears (G2–G5), with lower gears being used on uphill terrain and higher gears at higher velocities on level and slight downhill terrains. When velocity is further increased at steeper downhills, a steady tucked posture is applied. Specifically, G2 is an uphill technique with an asymmetrical poling action on every second leg stroke, G3 is used in level and moderate uphill inclines and performed with one poling action for every leg stroke. G4 is employed on level terrain with a symmetrical poling action on every second leg stroke, and G5 is mainly used in downhill slopes, where only skating strokes are performed. In addition, the arms could either be used to increase propulsion or be tucked in front of the body. Typical movements across the phases of the different sub-techniques are illustrated in Andersson et al. [2] and Nilsson et al. [3].

Since the various sub-techniques are used in different conditions, the impact of opposing forces will differ substantially. However, although extensive research has been conducted on the physiology and biomechanics of XC skating [1, 4, 5], few studies have considered the impact of aerodynamic drag. The aerodynamic drag force is caused by a combination of the pressure difference between the front and back of the body (pressure drag) and the surface

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friction due to the viscous effects of the flow (viscous drag) [6] and can be formulated as

$$F_D = \frac{1}{2}\rho V^2 C_D A, \tag{1}$$

where A is the projected frontal area, C_D the drag coefficient, V the relative velocity, and ρ the air density. In research on sports aerodynamics, the drag coefficient and frontal area (1) are often combined into a parameter called drag area ($C_D A$), which is proportional to the drag force [7]. The drag coefficient is dependent on the surface roughness, shape of the object, and the Reynolds number (Re). Re describes the flow properties and is affected by the flow velocity, size of the object and climatic factors. As the climatic factors and the size of the object (athletes) seldom change significantly in sport aerodynamic investigations, Re dependency is often regarded as a velocity dependency. Re dependency of a bluff body, such as a human, is complex due to the chaotic nature of turbulence, but investigations in alpine skiing have shown that C_D is Re dependent in the region < 20 m s^{-1} [8]. However, in the dynamic sub-techniques (G2–G5) in XC skiing, the shape and orientation of body segments continuously change depending on sub-technique, skiing velocity, cycle rate, and individual variations. Accordingly, this could potentially lead to a more complex relationship.

The first study investigating the impact of aerodynamics on XC skiing was done by Bilodeau et al. [9] who investigated the difference in heart rate between leading and drafting positions during classical and skate skiing on snow, resulting in a 4–6% reduction in heart rate for the drafting position in both styles. Spring et al. [10] found a 25% decrease in drag when shielding a skier in a tucked position. More recently, Ainegren et al. [11] examined the effect of drafting behind another skier, which showed a positive effect on reduced A and lower propulsive force, oxygen uptake, and heart rate for the drafting skier at high speeds, but not at lower speeds. In addition, head wind caused a pronounced increase in these variables at high speeds. In a different context, Leirdal et al. [12] compared high, moderate, and deep postures on aerodynamic and metabolic variables when simulating the leg movements in the skating technique using a slide board on a force plate in a wind tunnel. The results showed a 30% reduction in F_D from high to deep posture, with no difference in heart rate and oxygen uptake during a 3-min maximal test. However, none of the abovementioned studies compared different sub-techniques.

To examine the influence of sub-technique, Ainegren and Jonsson [13] compared $C_D A$, A, and C_D in classical and skating sub-techniques for a male skier standing on a force plate in a wind tunnel in static postures. The results showed large differences between the skating sub-techniques, with lower values of $C_D A$ found for higher gears. However, measurements were made on static postures at one speed per sub-technique, selected based on expected mean speed. Thus, possible $C_D A$ variations with speed, i.e., through Re dependency, were not considered. In addition, the use of static postures neglects the difference in flow behavior around static objects and time average measurement of dynamic motion (dynamic test), including the influence of different cycle rates. In this context, D'Auteuil et al. [14] investigated cycle rates from 0.25 to 1.00 Hz in speed skating with both static and dynamic drag measurements. These showed negligible effect of frequency below 0.67 Hz, while the drag measurements were lower for higher cycle rates.

Due to the limited research on aerodynamics in XC skiing and the abovementioned limitations of previous research, the aim of this study was to investigate the influence of XC skating sub-techniques on aerodynamic drag with dynamic and static drag measurements in relevant velocity ranges.

2 Methods

2.1 Participants

Two female Nordic combined athletes (body height: 166.5 ± 4.9 cm, body mass: 55 ± 5.7 kg) from the Norwegian national team participated in this study. The athletes wore similar standard tight fitting cross-country skiing suits. Prior to the test, the athletes were informed of the study's purpose and the right to withdraw at any time. Both provided written consent to participate, and the study was conducted in accordance with the Declaration of Helsinki [15]. The Regional Committee for Medical and Health Research Ethics waived the requirement for ethical approval for this study. The ethics of the project was performed according to the institutional requirements at the Norwegian University of Science and Technology. Approval for data security and handling was obtained from the Norwegian Centre for Research Data.

2.2 Experimental setup

The wind tunnel measurements were carried out at the Norwegian University of Science and Technology (NTNU). The wind tunnel has a cross-section of 4.9 m^2, can produce wind speed up to 20 m s^{-1}, a contraction ratio of 1:4.36 and a turbulence intensity of 0.3% [16]. The wind speed was measured with a pitot-probe, mounted 2 m upstream in the free air flow, and the drag force with a Schenk six-component force balance. A wooden plate (width 1.3 m and length 0.7 m) was mounted on the force balance used both for the static and dynamic measurements. A camera was mounted outside the wind tunnel and downstream, used to film the side and rear view of the athletes. A live video feed was shown on a screen mounted underneath the glass floor in front of the participant with graphical guidelines superimposed to help the athlete keep the intended posture or movement. The setup was similar to recent investigations in alpine skiing, ski jumping, and speed skating [6, 17, 18].

2.3 Sub-technique velocity distributions

Typical velocity distributions for each sub-technique were found based on data from 96 runs previously used as training and validation data for a machine learning technique to automatically classify sub-techniques, following the approach used by Strøm et al. [19]. The data were collected with an integrated Global Navigation Satellite System (GNSS) and inertial measurement unit (Optimeye S5, Catapult Innovations, Melbourne, Australia) during international FIS-regulated XC skiing time-trial competitions on six different FIS-homologated courses, utilizing the skating technique on snow. The unit was placed between the scapulae either in a dedicated vest or in a pocket in the race bib. The velocity was found from the GNSS data, and the sub-technique was found based on the inertial measurement unit data.

2.4 Test protocol

Both static and dynamic measurements were performed in sub-techniques G3–G4 to compare static and dynamic measurements, while G2 and G5 were only measured dynamically and statically tucked positions, respectively. Measurements were performed for the defined velocity ranges from the GNSS data for each of the techniques.

For the static positions, a sampling time of 20 s was chosen, with a sampling rate of 2 kHz. The sampling time was chosen so that the athletes would be able to maintain a consistent movement throughout the measurement. Three measurements were performed for all positions, and the mean value was used. The static measurements mimicking the dynamic movements in sub-technique G2–G5 were performed in accordance with Ainegren et al. [13], where the participant imitated postures during the movement of the sub-techniques, and the drag was averaged over the phase.

The dynamic tests were performed with a sampling time of 60 s and a sampling rate of 2 kHz, where the participant mimicked the defined movement on the force balance. Before starting each test, the participants performed a short training session mimicking the sub-technique under supervision of their coach to ensure that the movement was similar to real-life skiing. The athletes chose their own cycle rate during the training session, and a metronome was used during the test to assist them in keeping this rate. The athletes moved from one foot to the other without sliding sideways on the force balance. G3 was measured a total of six times per athlete, with two different cycle rates, both to check the repeatability of the tests and the influence of cycle rate. Based on the high repeatability of G3, i.e., low variation between the measurements, it was found to be sufficient with one dynamic measurement for the other sub-techniques.

There were large variations in the athletes' technical execution in G5 and tuck. To investigate these variations, two variants of both G5 and tuck were considered. Dynamical measurements were performed in G5 with arms tucked in front of the body and with arms out in the free air stream, shown in Fig. 1, to emphasize the aerodynamic importance of the arms in G5.

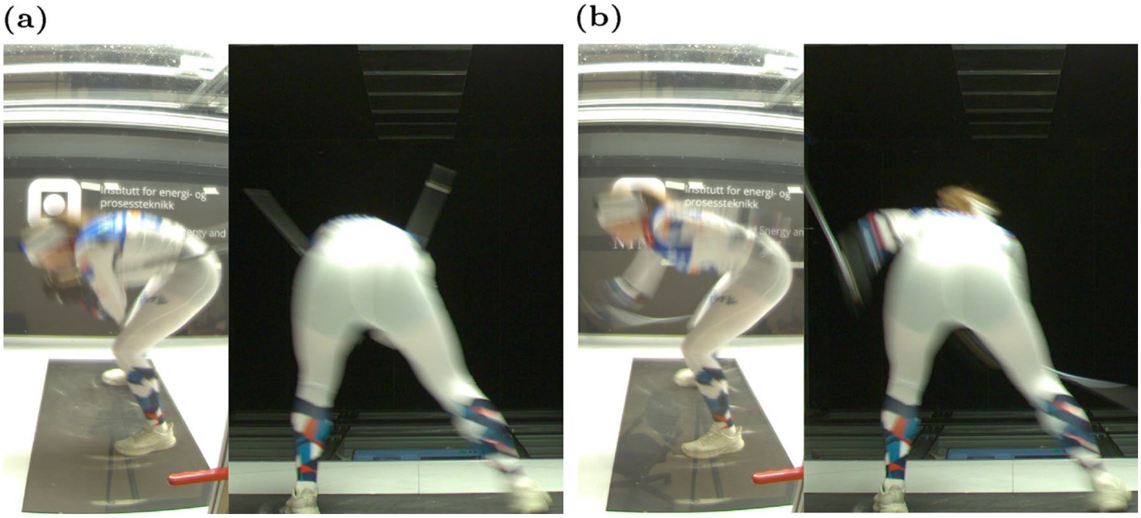

Fig. 1 Snapshots of dynamic measurement of G5 with arms tucked in front of the body in (**a**) and out in the free air stream in (**b**)

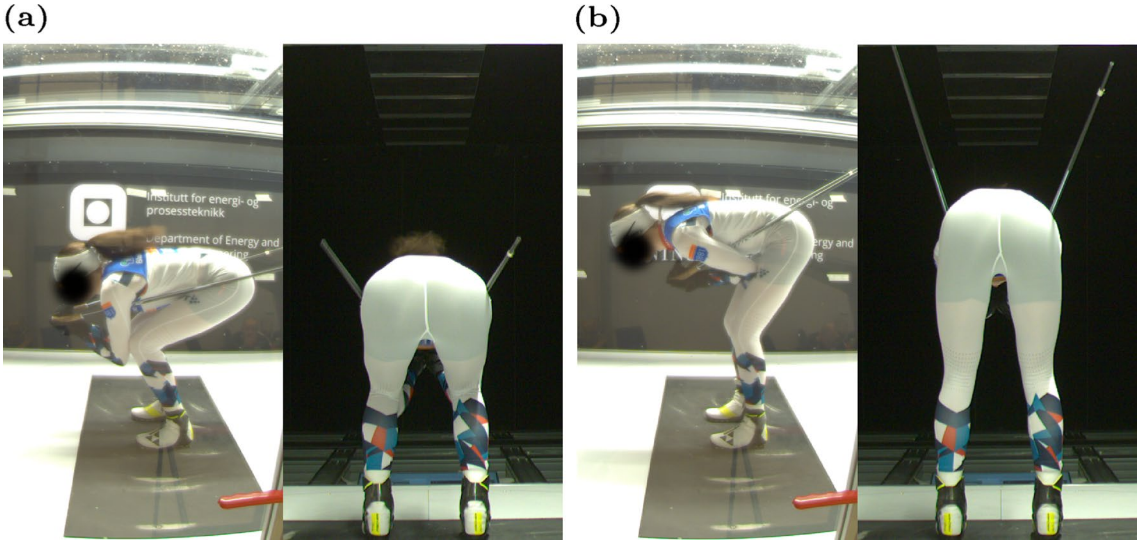

Fig. 2 Example pictures of the normal low tuck position in **(a)** and a tucked position with straight legs in **(b)**

Table 1 Calculated frontal area and the percentage difference between the two participants in the anatomical position and sub-techniques

Position	A1 (m^2)	A2 (m^2)	Difference (%)
Anatomical	0.514	0.540	5.0
G3	0.490	0.514	4.9
G4	0.497	0.530	6.7
G5	0.340	0.348	2.4
Tuck	0.241	0.250	3.8

In addition, low and high tuck postures, shown in Fig. 2, were compared at one speed to highlight some of the outer extremes of downhill postures.

The aim of these measurements was to examine how air drag can be influenced in these positions. Further investigation into various arm and tucked positions was considered to be outside of the scope of this study and have been investigated in alpine skiing [6, 20].

2.5 Frontal area measurements

The participants replicated the defined static tests performed in the wind tunnel in front of the green screen, and the frontal area was calculated from counting non-green pixels and converting pixels to m^2 from a known reference frame, as described by Elfmark et al. [18]. To calculate the frontal area of the dynamic sub-techniques, snapshots of the frontal area through the motion of each technique were calculated, and the mean was used in a similar procedure as used by Ainegren et al. [13]. The frontal areas of the two participants and the percentage difference between them are displayed in Table 1.

Example pictures from the calculation of the standard anatomical position and snapshots through the G3 movement are shown in Fig. 3.

On average, the difference in frontal area between the two participants was 5.5% in the upright posture sub-techniques (anatomical and G3–G4). The difference between the participants was smaller in G5 and tuck due to different technical execution, i.e., how compact their postures were.

2.6 Blockage correction

When performing wind tunnel measurements in a closed wind tunnel, blockage correction should be considered if the participant blocks 3–10% of the wind tunnel cross-section or more [21, 22]. In this case, the air flow is forced through a smaller area, which accelerates the flow due to continuum mechanics. This effect should be corrected to compare postures, athletes of different frontal areas, or to generalize findings to field conditions [8]. However, how to accurately correct for blockage for complex bluff bodies such as humans, and especially for cases with dynamic movement and constant changes in the frontal area is unknown. Hence, blockage correction will be assessed, when deemed necessary, clearly stated and evaluated as an uncertainty of this investigation. For the comparison between athletes, both corrected and uncorrected values will be presented for transparency. The correction model used will be

$$C_{Dc} = \frac{C_{Du}}{1 + \theta C_{Du}(A/CS)}, \quad (2)$$

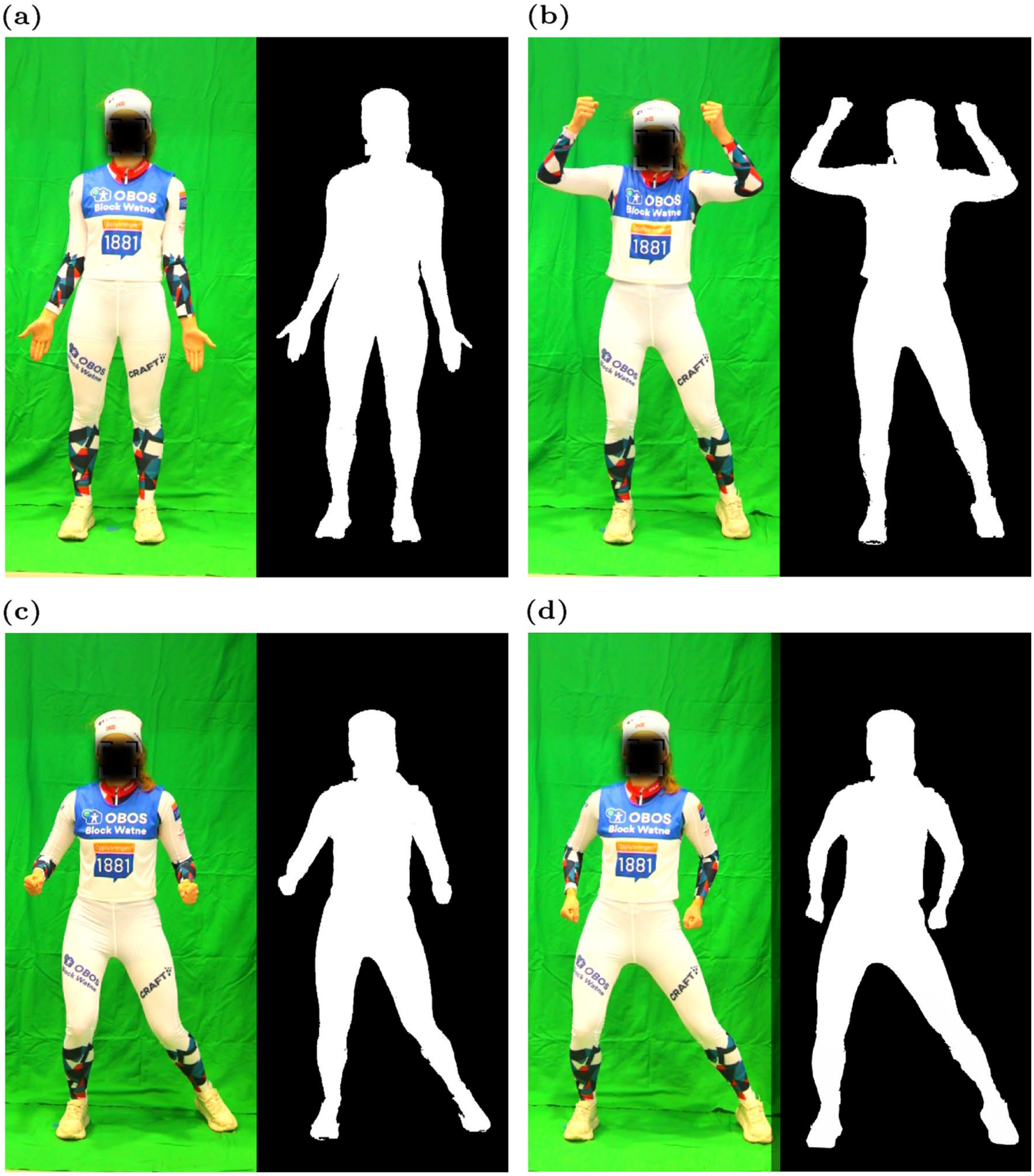

Fig. 3 Frontal area calculation example, where the athlete's frontal area is calculated by converting a picture in front of a green screen into a binary picture. The anatomical position of participant A1 is shown in **(a)** and snapshots through the sub-technique G3 in **(b)**–**(d)**

as suggested by Maskell [23]. In (2), C_{Dc} and C_{Du} are the corrected and uncorrected drag coefficient, respectively, θ the blockage constant, A the frontal area of the participant, and CS the cross-section area of the wind tunnel ($CS = 4.9\ \mathrm{m}^2$). The blockage constant was set to $\theta = 1.15$, found by Elfmark et al. [8] as the best fit for a standing posture in alpine skiers.

3 Results

3.1 Dynamic and static measurements

The difference between dynamic and static measurements

Table 2 Drag areas and percentage difference between static and dynamic measurements of sub-techniques G3 and G4 for the two skiers. Standard deviation ($n = 3$) is shown for all measurements except dynamic testing for G4 as only one measurement was performed per athlete

Athlete	Sub-technique	Speed ($m\ s^{-1}$)	Test	$C_{Du}A$ (m^2)	Difference (%)
A1	G3	6	Dynamic	0.446 ± 0.004	− 7.5
			Static	0.482 ± 0.007	
	G4	8	Dynamic	0.411	− 11.2
			Static	0.463 ± 0.011	
A2	G3	6	Dynamic	0.480 ± 0.003	− 2.8
			Static	0.494 ± 0.015	
	G4	8	Dynamic	0.445	− 7.3
			Static	0.480 ± 0.006	

was assessed for G3 and G4. Comparisons are shown in Table 2, with a mean drag reduction of 7.2% between dynamic and static measurements. Blockage correction was not performed as the frontal area was assumed to be unchanged for the comparisons for each participant.

From Table 2, we can see that by testing static positions through the phase, an aerodynamic investigation of a dynamical movement may be inaccurate and result in too high drag measurements. The standard deviations of the dynamic tests were also generally lower than for the static tests; hence, the repeatability of the dynamic tests is better than for the static positions. For this reason, dynamic tests were used for all further analyses of the movements of G2–G5.

3.1.1 Cycle rate

The change in drag area as a function of cycle rate was assessed in G3 and shown in Table 3. No blockage correction was applied as the mean frontal area was assumed to be the same for the different cycle rates.

Only small changes were observed between the cycle rates within the range of the standard deviation. However, a trend against a lower drag area was observed for higher cycle rates.

3.2 Sub-technique and drag area as a function of velocity

The velocity distribution in the sub-techniques and the corresponding drag areas, averaged over the two participants, are shown in Fig. 4.

Drag areas were corrected for blockage as the frontal area changes for the different techniques. The drag area was significantly influenced by velocity, as a decrease was observed from 2 $m\ s^{-1}$ to around 10–12 $m\ s^{-1}$, where it started to plateau. Only small differences within the uncertainty range were found between the sub-techniques where the overall frontal area was relatively similar (G2–G4). In G5, the athletes were able to reduce air drag by 21.7% by keeping the arms tucked in front of the body. The increase in air drag from a typical low tuck to a high tuck (i.e., tucked upper body with straight legs) was 23.0%.

3.3 Difference between athletes

Drag areas of all velocities in G3 and G4 are displayed in Table 4. The other sub-techniques (G2, G5 and tuck) were not compared between the athletes as large individual differences in the technical execution of these sub-techniques were observed. Both uncorrected and corrected drag areas are presented, as A2 had a 5.3% larger frontal area in G3 and 6.7% in G4.

Mean differences of 8.7 ± 1.6% and 7.8 ± 1.3% were found for the uncorrected and corrected drag areas, respectively. As there was a 6% frontal area difference between the skiers in these two sub-techniques, around 2% was not directly described by the change in frontal area.

4 Discussion

This study examined how air drag in XC skiing varies with skating sub-technique and velocity. The main findings were that drag area depends on velocity in the range 2–12 $m\ s^{-1}$, while sub-techniques with an upright posture and relatively

Table 3 Mean drag areas with standard deviation (n=3) and percentage difference between preferred and high cycle rates in the G3 skating sub-technique for the two skiers

Athlete	Sub-technique	Speed ($m\ s^{-1}$)	Cycle rate (Hz)	$C_{Du}A$ (m^2)	Difference (%)
A1	G3	9	1.00	0.422 ± 0.003	1.4
			1.25	0.416 ± 0.001	
A2	G3	9	0.97	0.454 ± 0.001	2.4
			1.22	0.442 ± 0.004	

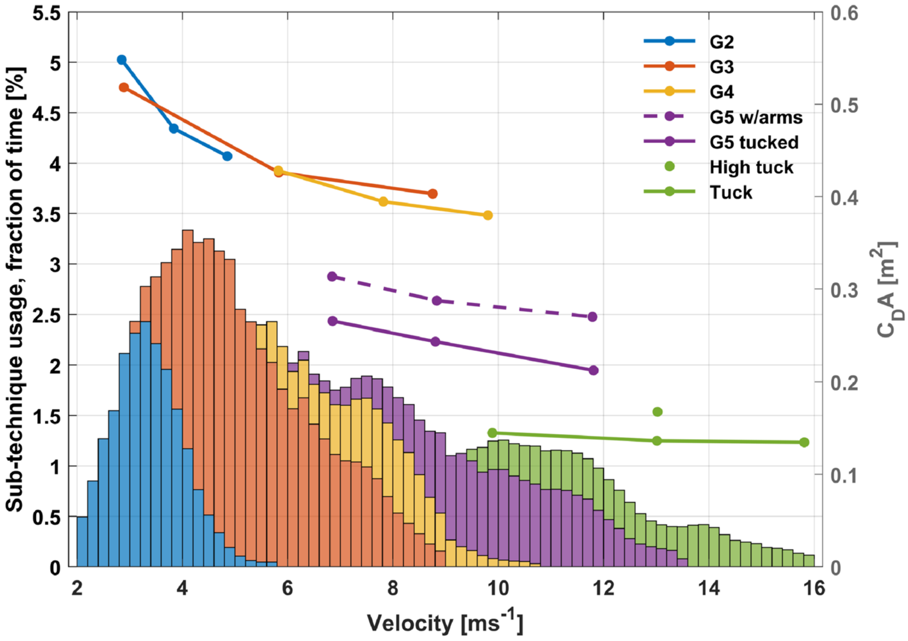

Fig. 4 GNSS data of typical velocity distribution of XC skate skiing sub-techniques (G2–G5 + tuck) and the corresponding drag area's dependency on velocity. Averaged corrected drag areas ($C_{Dc}A$) of the two participants are shown, with dynamic measurements used for G2–G5 and static measurements for tuck. G5 is displayed both with arms tucked in front of the body and arms placed in the free air stream (dashed line). The low tuck position is indicated in green, and the single green mark indicates a higher, more upright, tuck posture where the participant's legs were straight

Table 4 Comparison of measured $C_{Du}A$ (uncorrected) and $C_{Dc}A$ (corrected) values for the two athletes in sub-techniques G3 and G4 for their respective velocity ranges

Sub-tech.	Speed (m s^{-1})	$C_{Du}A$			$C_{Dc}A$		
		A1 (m^2)	A2 (m^2)	Diff (%)	A1 (m^2)	A2 (m^2)	Diff (%)
G3	3	0.548	0.606	10.5	0.486	0.530	9.2
	6	0.434	0.467	7.6	0.394	0.421	6.9
	9	0.416	0.442	5.4	0.379	0.401	5.8
G4	6	0.445	0.490	10.2	0.403	0.440	9.2
	8	0.411	0.445	8.3	0.375	0.403	7.5
	10	0.392	0.429	9.3	0.359	0.390	8.5

similar frontal areas (G2–G4) did not influence drag area considerably.

The velocity dependency (Re dependency) in aerodynamic drag was expected from Elfmark et al. [8], where Re dependency of alpine skiers was investigated. The drag of the alpine skiers was found to be dependent on velocity for velocities <25 m s^{-1}, with the difference starting to plateau around 15 m s^{-1}. The differences in movement pattern between the sub-techniques are regarded relatively large from a biomechanical perspective, particularly between G3 with one poling action for every leg stroke versus G2/G4 with one poling action every second leg stroke. However, the difference from an aerodynamic perspective was relatively small due to similar frontal areas when being averaged over a cycle.

Another key finding was that air drag decreased within a given sub-technique when measurements were done dynamically, compared to averaging over static measurement through the motion. Specifically, the air drag was on average 6.1% lower for dynamic than static measurements, indicating that XC skiing movements should be tested dynamically when evaluating air drag. This finding also indicates that there are dynamic effects affecting the air drag. This may be associated with how cycle rates influence air drag since the cycle rates in this study were in the 0.95–1.25 Hz range. This concedes well with the findings of D'Auteuil et al. [14], who found a drag reduction for cycle rates higher than 0.67 Hz. In our study, the chosen cycle rate had minimal influence on the air drag. For example, A2 had a lower difference than A1 in the G3 position which could be explained by A2 performing the dynamic movement in a somewhat more upright position than the static postures, which was observed in the picture evaluation of the measurements. However, the overall influence of cycle rate was minimal, and the underlying reasons for differences between dynamic and static measurements require further elucidation in future studies.

As the only study so far, Ainegren et al. [13] measured the drag force, drag area, and frontal area of different sub-techniques in XC skiing. Here, aerodynamic differences were found between the upright posture sub-techniques G2–G4 based on static measurements for one typical speed within each sub-technique. Thus, although air drag and drag area was measured for each sub-technique, whether the variations found in aerodynamic parameters were due to speed differences or differences in movement patterns between sub-techniques was not investigated. The main results of Ainegren et al. [13] are in overall agreement with our findings, but our measurements included a range of speeds for each sub-technique and indicate that the aerodynamic differences are mainly a function of skiing speed rather than sub-technique. This is also emphasized by the fact that Ainegren et al. [13] systematically found the largest drag coefficients for the sub-techniques where the measured speed was lowest. The results from our study also indicate that the drag area of the dynamic sub-techniques in the aforementioned study [13] may be overestimated, as all are measured by averaging static postures.

Athletes have limited opportunity to influence aerodynamic parameters in the G2–G4 sub-techniques, as producing propulsive forces effectively in the upright posture sub-techniques includes certain constrains on the motion pattern. However, these results are still valuable for calculating the effect of air drag at given sub-techniques and speeds. In G5, an athlete has more flexibility in how to perform the movement as G5 can either be performed while moving the arms from side to side, aiming to maximize leg propulsion, or with arms tucked in front of the body to reduce aerodynamic drag. The speeds are generally higher compared to other sub-techniques, and the air drag increases exponentially with velocity (eq. (1)). The aerodynamic influence of the arms in sports are complex, and a full investigation also including dynamic effects was outside the scope of this investigation. However, large similarities can be drawn to alpine skiing where the arms have been seen to be highly influential for air drag [20]. In our study, it was found that a XC skier can decrease air drag as much as 21.7% by keeping the arms tucked in front of the body. It is worth noting that when the athlete had the arms tucked in front of the body, the overall position changed somewhat (Fig. 1), which also could influence the difference. Nevertheless, this comes with the compromise of also producing less propulsive force, which must be considered in the overall evaluations of its effectiveness while skiing.

Similarly, for G5, a XC skier has flexibility in how a tucked downhill posture can be performed. Unlike alpine skiing disciplines like downhill and super-G, where the main aim is to reduce drag, a XC skier needs to balance the reduction of air drag against muscular recovery. Hence, a variety of strategies can be used in a downhill, either by minimizing the aerodynamic drag as much as possible or by finding some compromise in a more upright posture to also ensure a better recovery. Thus, knowledge on this topic is important for evaluating the pros and cons of both strategies to make the optimal choice.

The speeds are even higher in the downhills than in G5, so a too high position could lead to a large time loss. As for the arms in G5, a full investigation of the tucked position of different postural changes in this position was considered to be outside of the scope of this study, but the study refers to Elfmark et al.'s [6] investigation focusing on postures relevant in alpine skiing. From recent studies [6, 20], it is evident that a XC skier should always strive to have the arms tucked in front of the body and a low torso angle in a downhill, since it is beneficial from an aerodynamic perspective and should not compromise recovery significantly. In addition, outer extremes of the tucked position were tested in terms of a low tuck and a high tuck with straight legs. The difference between these two postures was 23%, emphasizing the importance of optimizing the tucked position in XC skiing as well.

For the results to be generalizable and applicable for others, it is important to understand if the difference found in drag area between the two athletes could be fully explained by the difference in frontal area ($C_DA \propto A$) for a given sub-technique. Some effects could occur if the difference in the size of the skiers is large, as Re would be affected. In this study, the difference in drag area between the athletes was 2% larger than the difference in frontal area. This discrepancy could be due to a difference between the measured frontal area and actual frontal area during the dynamic movement inside the wind tunnel because the actual blockage constant should have been larger or due to a change in Re. A blockage constant of $\theta = 5.5$ would have been needed to fully explain the difference between athletes, compared to the $\theta = 1.15$ used in this study. The large blockage constant theoretically needed to fully explain the difference, which indicates that there may be a larger difference in frontal area than estimated. However, an uncertainty of 2% with respect to the difference in athletes is still low compared to the measurements performed by Ainegren et al. [13]. Thus, the difference in drag coefficient due to the athlete was assumed to be low but should be further investigated in studies where blockage can be neglected, i.e., wind tunnels with larger cross-sections or in computational fluid dynamic simulations.

5 Conclusion

This study has given insights into the influence of XC skating sub-techniques and skiing velocity on aerodynamic drag. The drag area of a skier was found to be velocity dependent and decreasing for velocities < 12 m s^{-1}. No difference in air drag was found between the sub-techniques performed in upright postures (G2–G4). The drag area was on average 6.1% lower when the sub-techniques were measured dynamically compared to averaging over static positions throughout the movement. In G5 a skier can reduce air drag by 21.7% by tucking the arms in front of the body, compared to having the arms out in the free air stream. In downhill postures, maintaining a compact and low tucked posture decreased the air drag by 23.0% compared to a high tuck with straight legs.

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Data availability The empirical data referred to in this paper are available on request from the corresponding author, but are not public due to privacy restrictions.

Declarations

Ethical statement Prior to the test, the athletes were informed of the study's purpose and the right to withdraw at any time. Both provided written consent to participate, and the study was conducted in accordance with the Declaration of Helsinki [15].

Conflict of interest The authors declare no conflict of interest.

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