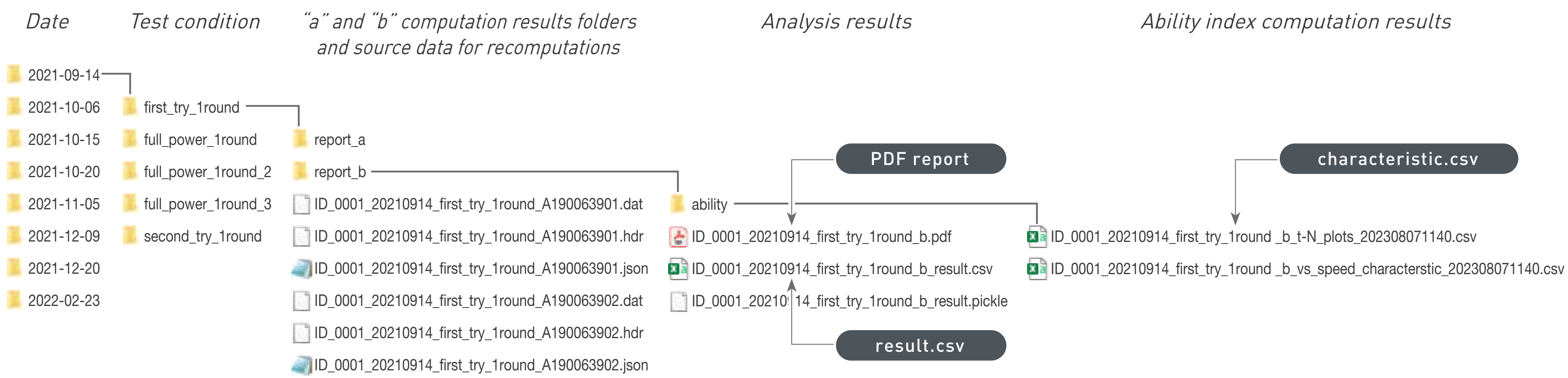
Push power measurement system
Understanding Reports and Data

HONDA

Report Structure

- **PDF reports (output as folders "_a" and "_b" representing 2 different computation methods)**
  - Page 1 — Presents data on the stroke recording the top speed
  - Page 2 — Presents synthetic data on the stroke recording the top speed and the 4 strokes immediately prior
  - Page 3 onward — Presents data for each stroke in order, starting with the 1st stroke
- **speed_characteristic.csv**
  Output of the relationships between various characteristics and speed
- **result.csv**
  Output of all internal computation results, including data used in creation of PDF reports
  Use this data if you wish to perform your own original analysis.



Understanding PDF Reports (Overall Layout) (1/2)

Date of measurement

ID number (or name)

Measurement condition (free-text entry)

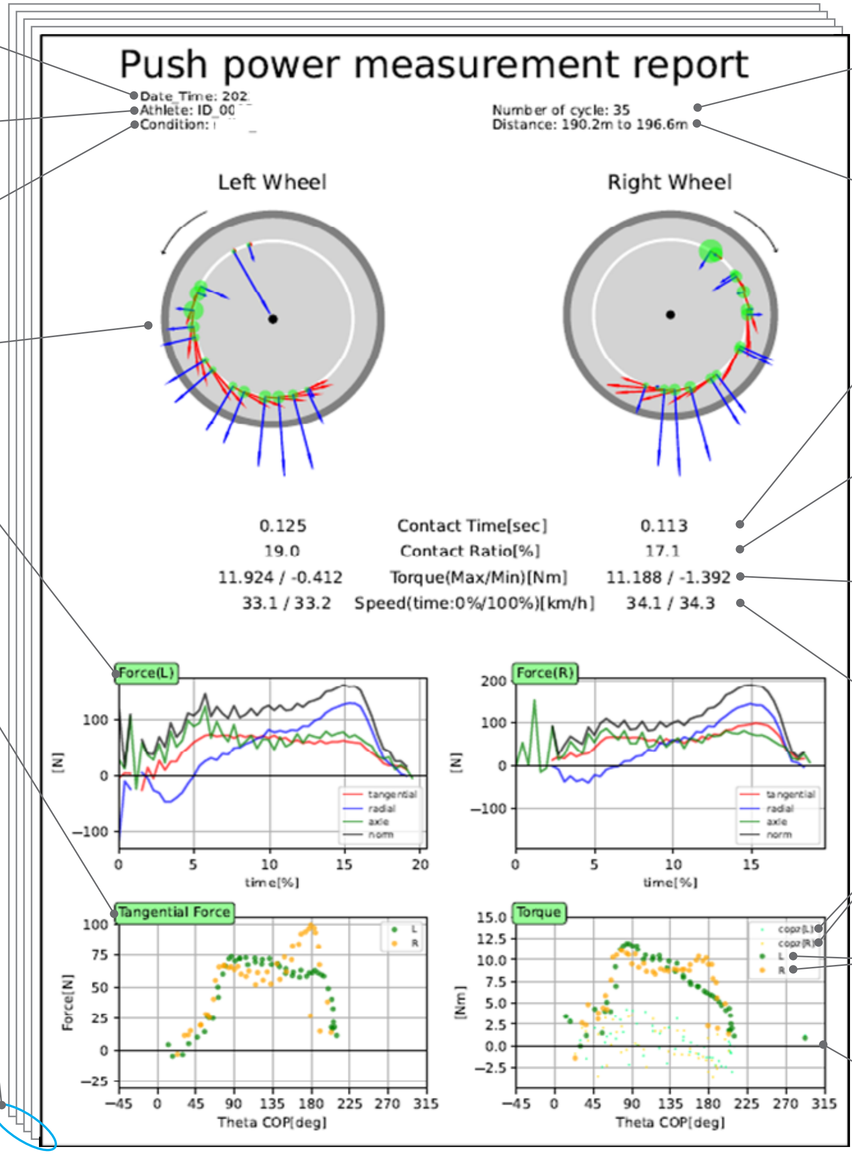
Force vectors (3 directions)
- Tangential force (red)
- Radial force (blue)
- Axial force (green)

- Force vector time-series data
- Norm (force magnitude) time-series data

Relationship between tangential force magnitude and point (angle)* of force application
*Guide to force application points
- Top: 0 deg
- Horizontal in direction of travel: 90 deg
- Bottom: 180 deg

1 page for each stroke

*Explanation of units
N: Newtons (10 N = approx. 1 kg)
deg: Degrees (right angle = 90 deg)
Nm: Newton-meters (1 Nm is the torque resulting, for example, from the application of 1 N of force to the tip of a 1-meter-long wrench)



Number of the cycle (stroke) since the start of the measurement

Distance traveled since the start of the measurement

Contact time

Contact ratio as a proportion of cycle time (1 cycle)

Maximum and minimum torque (a negative value indicates braking)

Speed at the start and end of the stroke

Torque applied to rotate the wheel about the point of glove contact (included in torque about the axle)

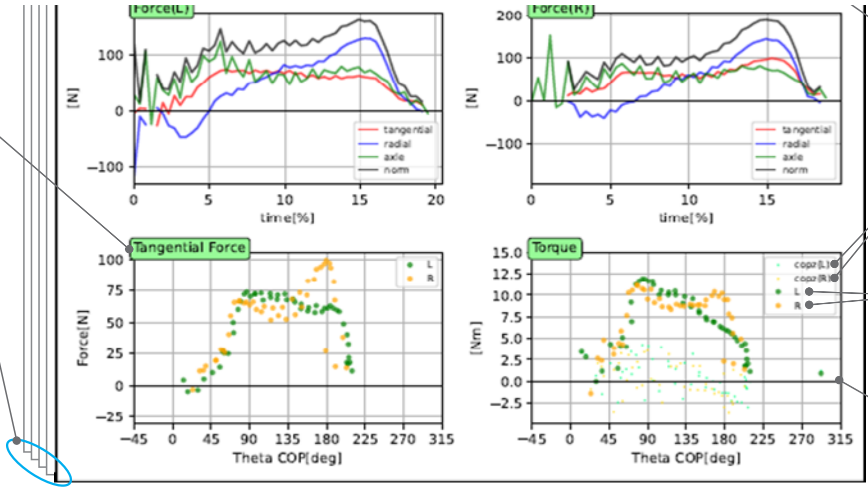
Torque about the axle (directly influences acceleration and deceleration)

Relationship between torque magnitude and point (angle)* of force application

Understanding PDF Reports (2/2)

Relationship between tangential force magnitude and point (angle)* of force application
*Guide to force application points
• Top: 0 deg
• Horizontal in direction of travel: 90 deg
• Bottom: 180 deg

1 page for each stroke

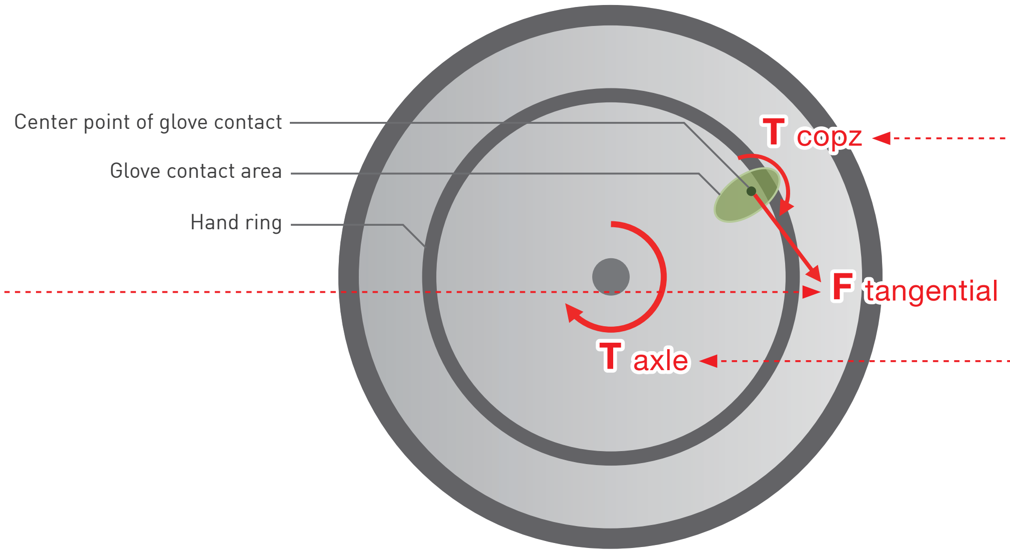


Speed at the start and end of the stroke

Torque applied to rotate the wheel about the point of glove contact (included in torque about the axle)

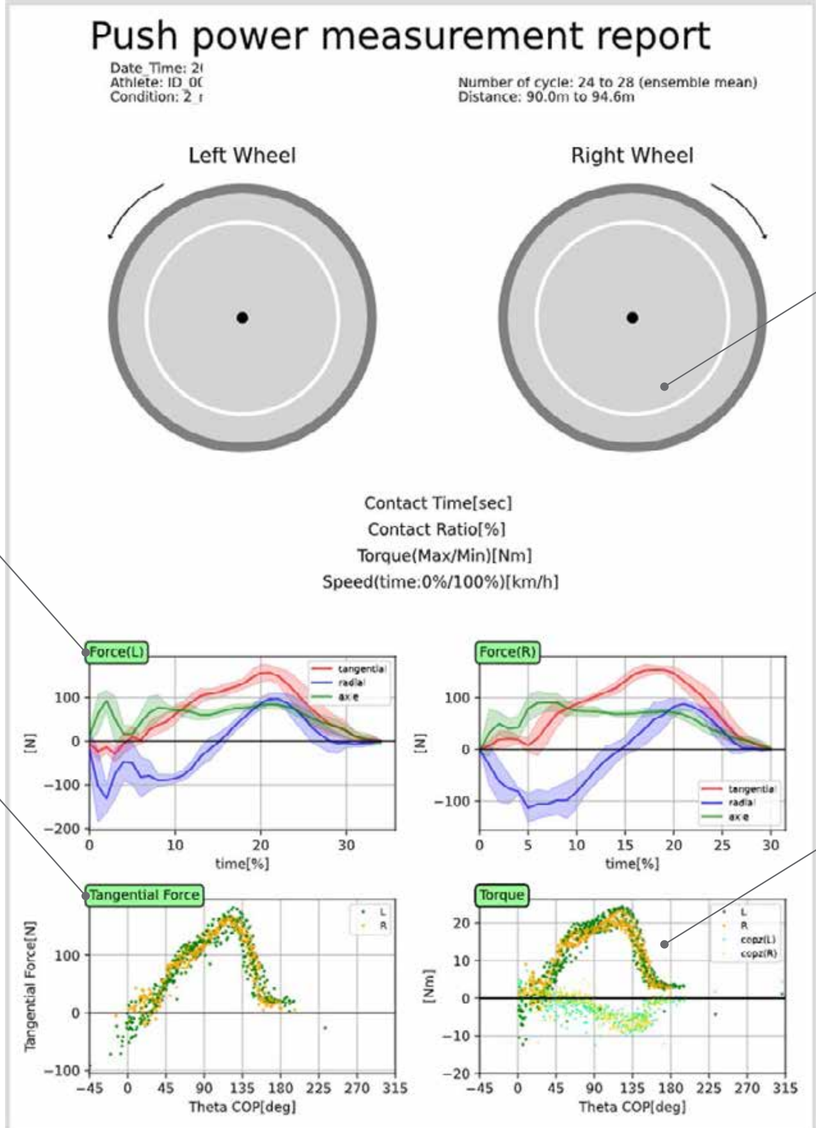
Torque about the axle (directly influences acceleration and deceleration)

Relationship between torque magnitude and point (angle)* of force application



Understanding Page 2 of PDF Reports

*To facilitate evaluation, page 2 provides a combined report on 5 cycles—the cycle achieving the top speed and the 4 immediately preceding cycles.



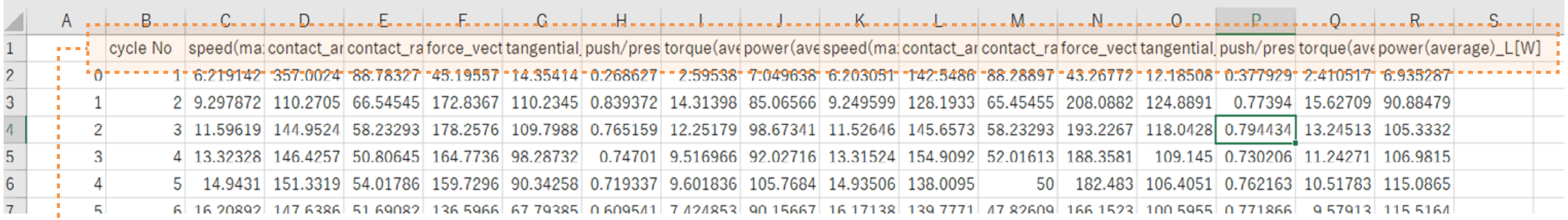
Force vectors are not shown as a drawing of force vectors for all 5 cycles would be complex.

- The solid lines are average waveforms representing time-series data of force vectors in 3 directions over 5 cycles.
- The bands of light shading represent the variation over 5 cycles.

The relationship between tangential force magnitude and the point (angle) of force application is plotted for all 5 cycles.

The relationship between torque and the point (angle) of force application is plotted for all 5 cycles.

Understanding CSV Files (*_vs_speed_characteristic.csv)



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1		cycle No	speed(ma	contact_ar	contact_ra	force_vect	tangential_	push/pres	torque(ave	power(ave	speed(ma	contact_ar	contact_ra	force_vect	tangential_	push/pres	torque(ave	power(average)_L[W]	
2	0	1	6.219142	357.0024	88.78327	45.19557	14.35414	0.268627	2.59538	7.049638	6.203051	142.5486	88.28897	43.26772	12.18508	0.377929	2.410517	6.935287	
3	1	2	9.297872	110.2705	66.54545	172.8367	110.2345	0.839372	14.31398	85.06566	9.249599	128.1933	65.45455	208.0882	124.8891	0.77394	15.62709	90.88479	
4	2	3	11.59619	144.9524	58.23293	178.2576	109.7988	0.765159	12.25179	98.67341	11.52646	145.6573	58.23293	193.2267	118.0428	0.794434	13.24513	105.3332	
5	3	4	13.32328	146.4257	50.80645	164.7736	98.28732	0.74701	9.516966	92.02716	13.31524	154.9092	52.01613	188.3581	109.145	0.730206	11.24271	106.9815	
6	4	5	14.9431	151.3319	54.01786	159.7296	90.34258	0.719337	9.601836	105.7684	14.93506	138.0095	50	182.483	106.4051	0.762163	10.51783	115.0865	
7	5	6	16.20892	147.6386	51.69082	136.5966	67.79385	0.609541	7.424853	90.15667	16.17138	139.7771	47.82609	166.1523	100.5955	0.771866	9.57913	115.5164	

Column name	Meanings
cycle No	Number of the cycle (stroke) since the start of the measurement
speed(max)_R[km/h]	Maximum speed on the right-hand side
contact_angle_R[deg]	Contact angle on the right-hand side
contact_ratio_R[%]	Contact ratio on the right-hand side (contact time relative to the time of 1 cycle)
force_vector_norm(average)_R[N]	Average magnitude of the force applied on the right-hand side (average during contact)
tangential_force(average)_R[N]	Average tangential force applied to the hand ring on the right-hand side* (average during contact)
push/press(average)_R[N]	Average proportion of tangential force applied to the hand ring relative to the press force (radial and axial directions) on the right-hand side* (average during contact)
torque(average)_R[Nm]	Average torque applied on the right-hand side (average during contact)
power(average)_R[W]	Average power applied to the wheel on the right-hand side (Note: This is the average for one entire cycle and includes sections of no contact)
speed(max)_L[km/h]	Same descriptions as above, but for the left-hand side
contact_angle_L[deg]	
contact_ratio_L[%]	
force_vector_norm(average)_L[N]	
tangential_force(average)_L[N]	
push/press(average)_L[N]	
torque(average)_L[Nm]	
power(average)_L[W]	

‹Note›

"Push" = tangential force

Press=√(radial force^2+ axial force^2)

(press force applied to the hand ring)

"Push/press":

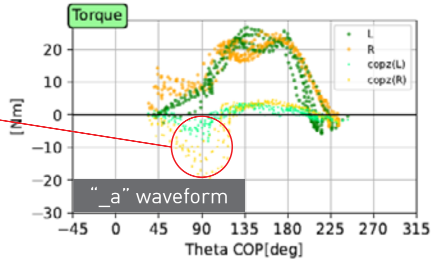
This is the proportion of tangential force (force in the direction of acceleration) relative to the press force (force to prevent slipping). The value is approximately 0.0–1.0. A value closer to 0 represents a smaller acceleration force and a larger press force to prevent slipping. A value closer to 1.0 indicates good balance, but a propulsion style achieving close to 1.0 when the hand ring is wet due to sweat or rain may result in slipping.

Procedure for Selecting Between "_a" and "_b" Computation Methods

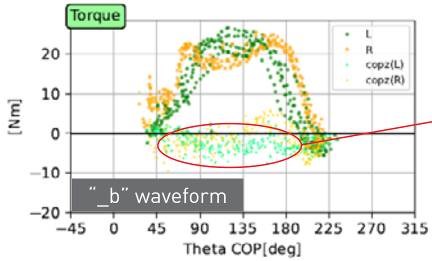
Open files "***_a.pdf" and "***_b.pdf" and compare the force vectors and graphs on pages 1 and 2. Determine which file ("a" or "b") shows waveforms closest to the ones envisaged.

Example

Torque about the glove contact point is abnormally high



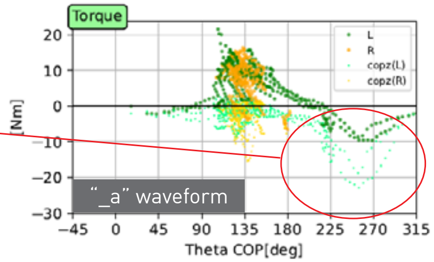
Compare



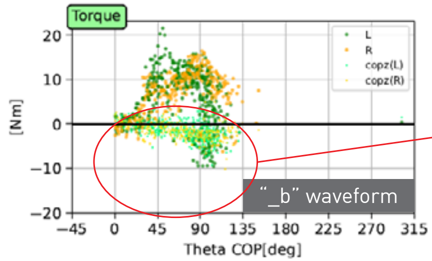
Torque about the contact point is valid—select "b"

Example

Angle of contact is not realistic



Compare



Angle of contact range is valid—select "b"

- If both "_a" and "_b" waveforms are good, select "b" results.
- If the "b" waveform is distorted, select "a" results.

Do not examine the differences between "a" and "b" as the computation methods differ. To compare athlete form or make other comparisons, compare "a" results with "a" results, or "b" results with "b" results.

Caution: *Keep in mind that "_b" computation results tend to be better, particularly at low speeds.
*Please understand there are accuracy limitations in computing the point of force application as related research is still in progress.

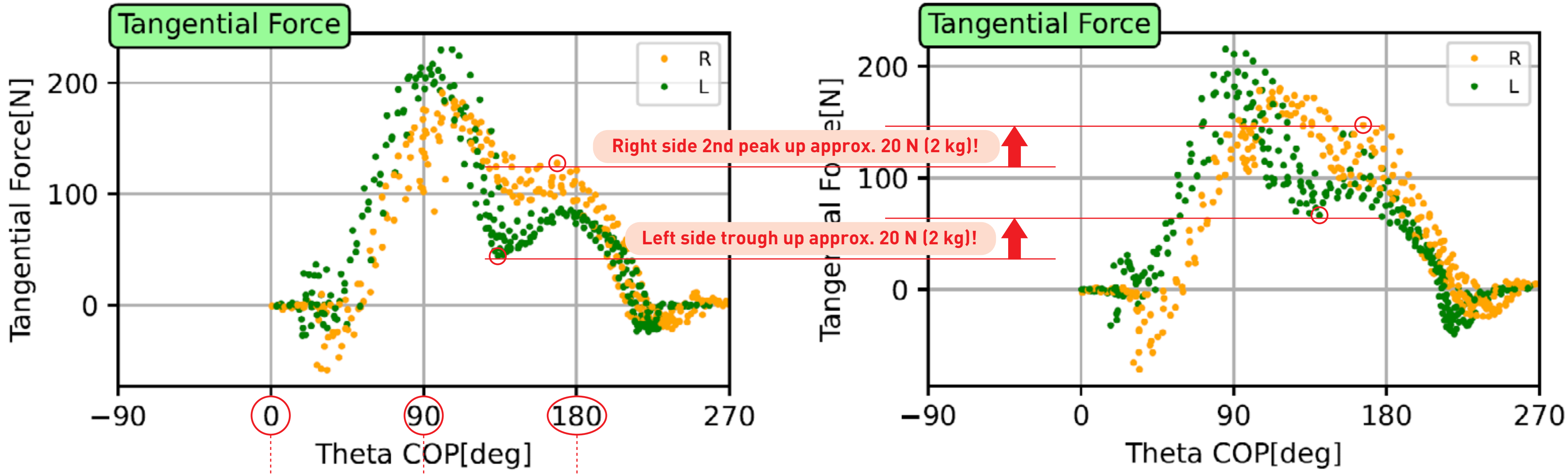
Analysis Examples

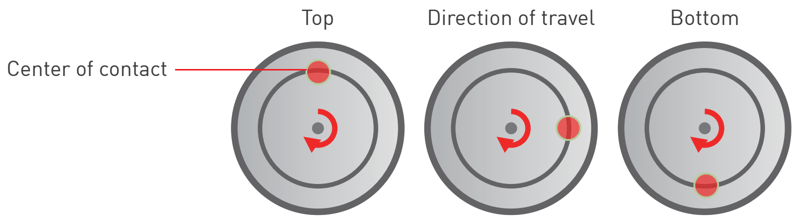
(1) Analysis Using PDF Reports

Example: Confirming the Benefits of Training

Reference Date

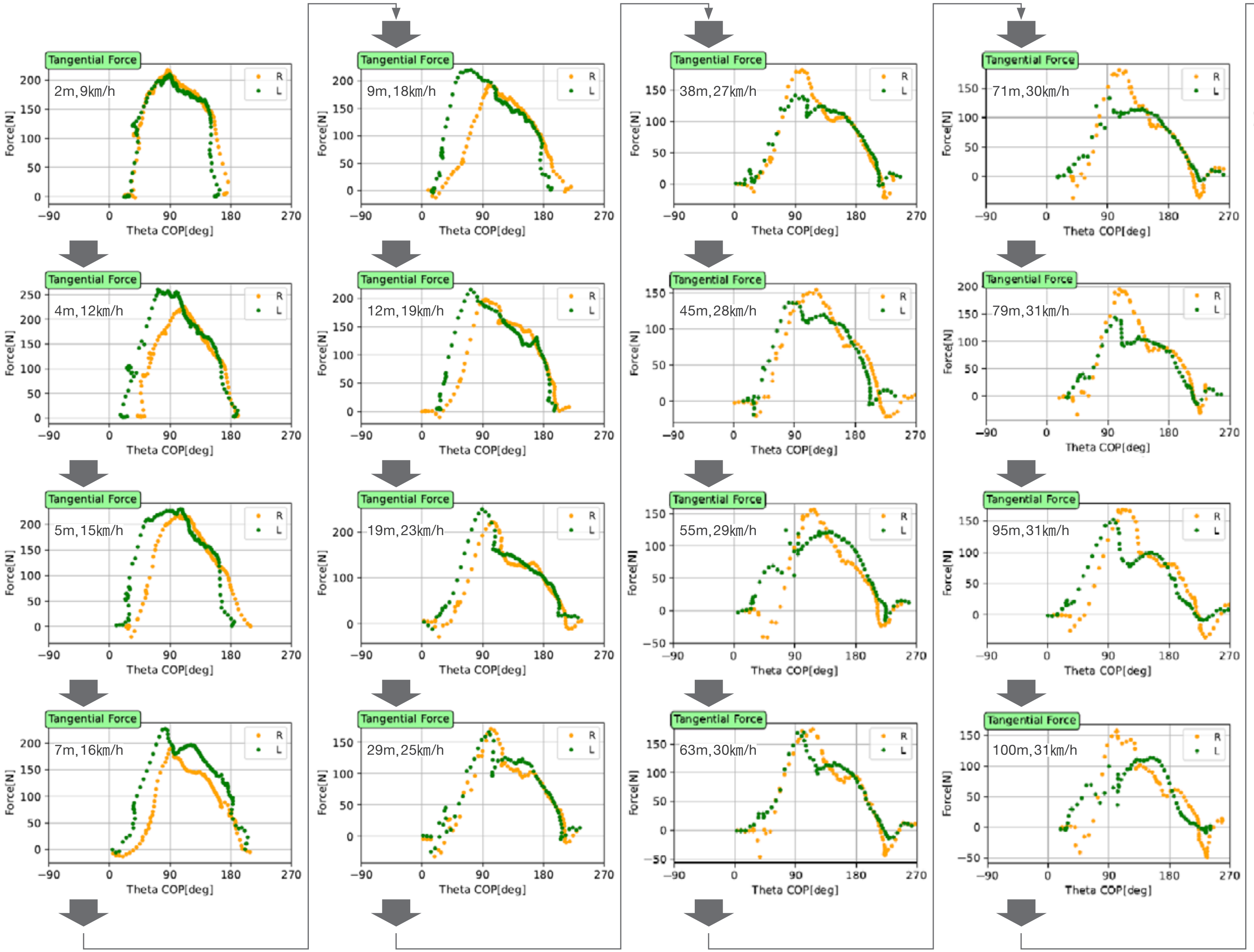
After Training





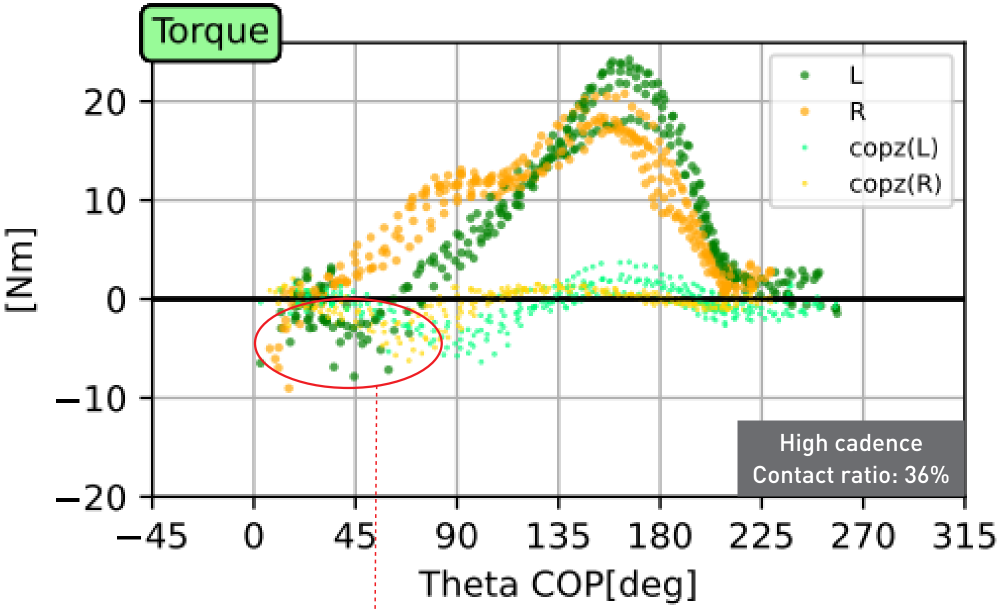
An improvement was observed in propulsion force waveforms.

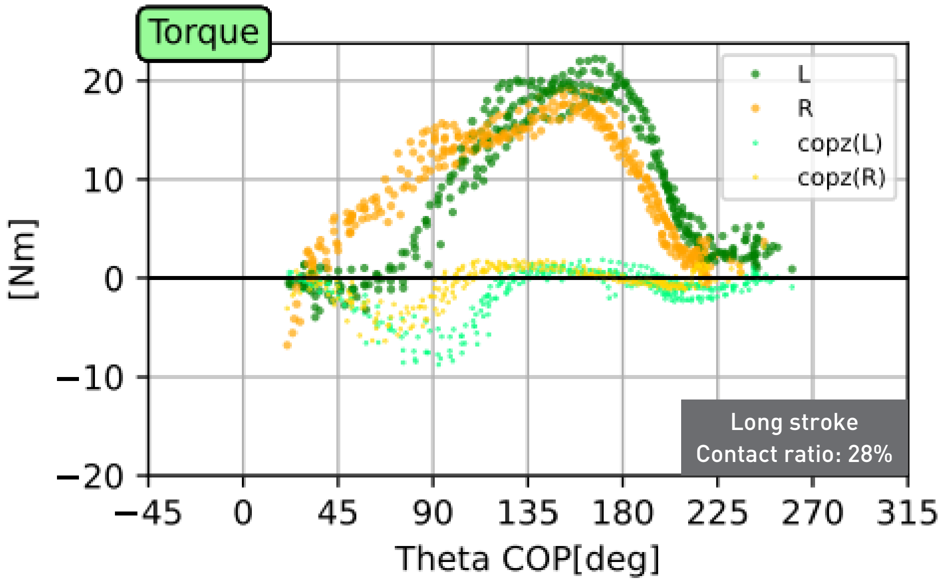
Example: Gain a Full Picture of Propulsion Force During Acceleration



Divergence of left and right sides was seen to increase as speed increased

Example: Compare High-Cadence and Long-Stroke Propulsion

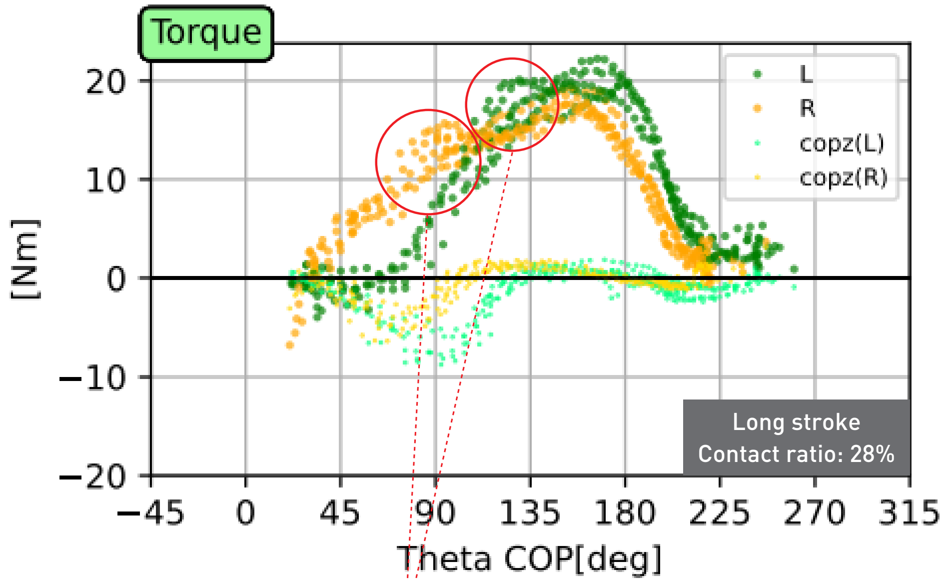


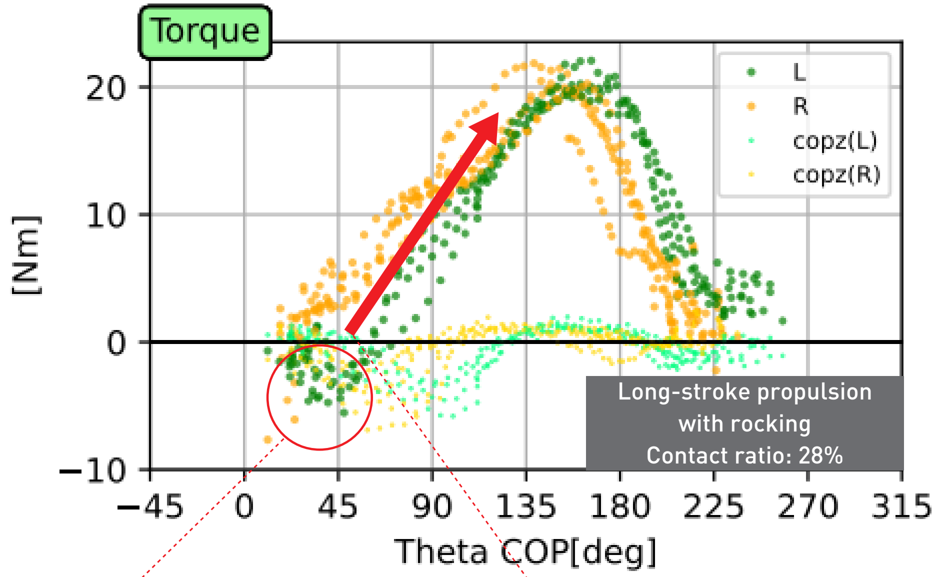


A braking component can be seen on the left side immediately after contact. This is likely because of the relatively busy style of high-cadence propulsion. One suggested reason for a braking component immediately after contact is hand speed not keeping pace with wheel rotation speed.

During high-cadence propulsion, a braking component was observed immediately after contact on the left side.
Otherwise, high reproducibility was achieved with both propulsion styles, indicating an ability to maintain consistent propulsion force.

Example: Compare Performance With and Without Rocking Body Motion





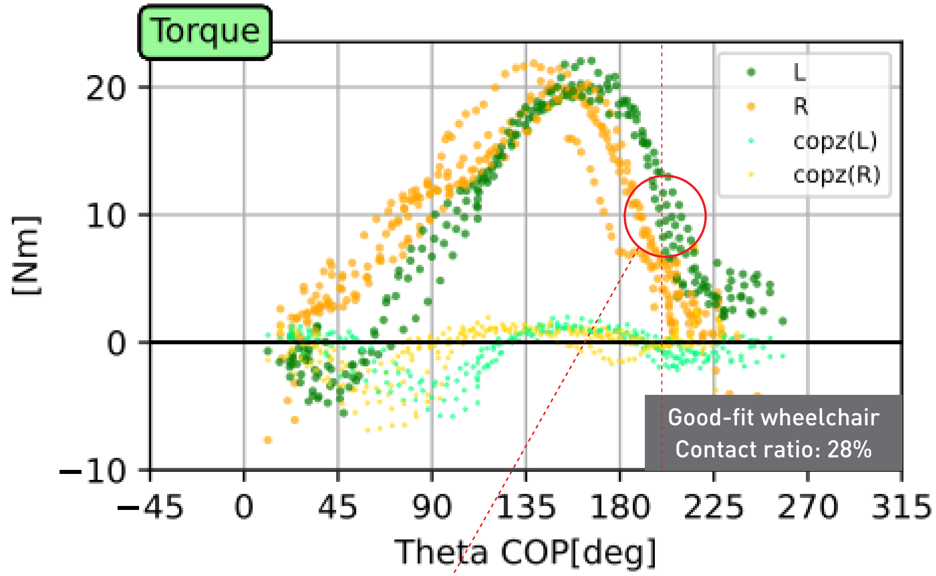
Force is uneven

The braking component is slightly more pronounced. Glove forward acceleration might be slightly insufficient due to preoccupation with up-down rocking of the upper body.

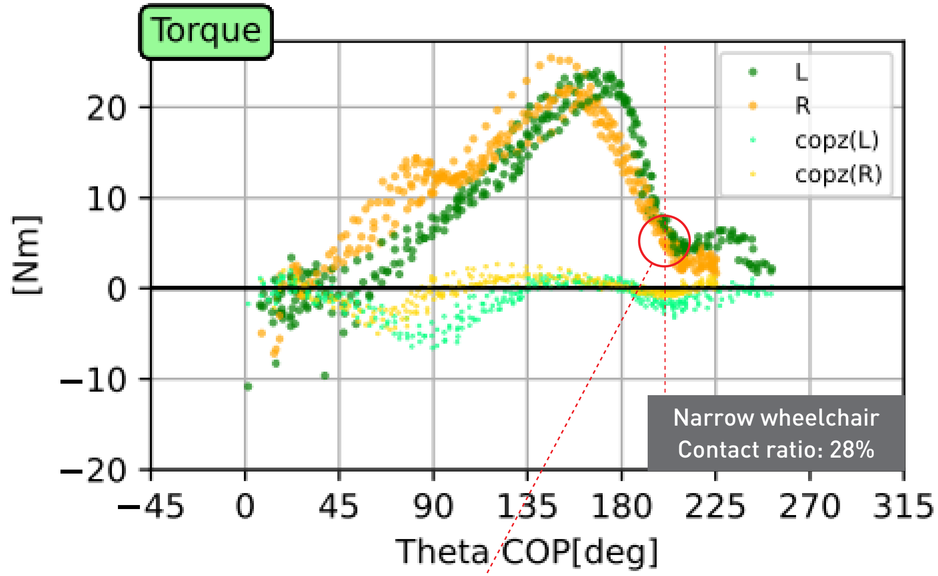
The peak is quickly reached as there is no unevenness of force, perhaps because of the momentum from rocking the upper body.

Force rises steadily to peak with no unevenness of force due to the up-down momentum of the upper body.
Conversely, there is a possibility that focusing on the up-down motion led to insufficient forward acceleration of the glove immediately before contact.

Example: Compare Performance with Different Racing Wheelchairs



Close to 10 Nm torque is generated on the left side even at 200 deg



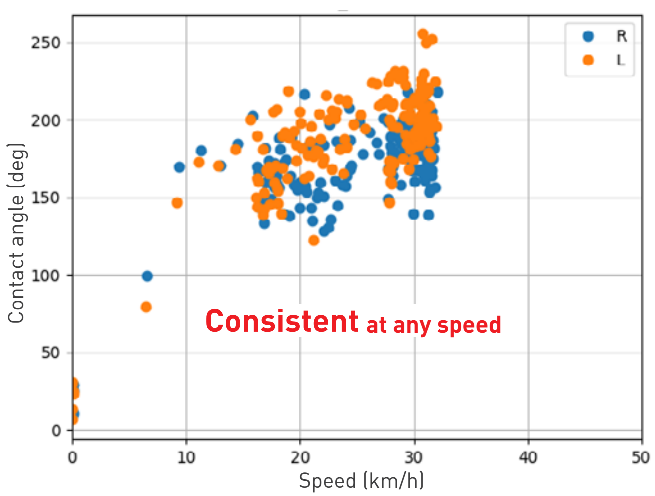
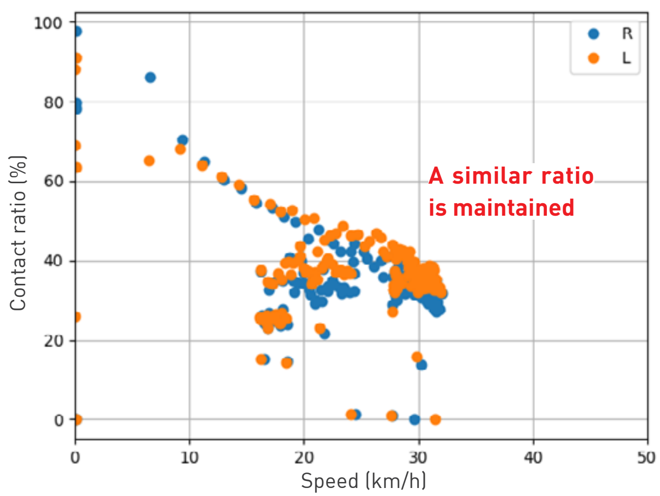
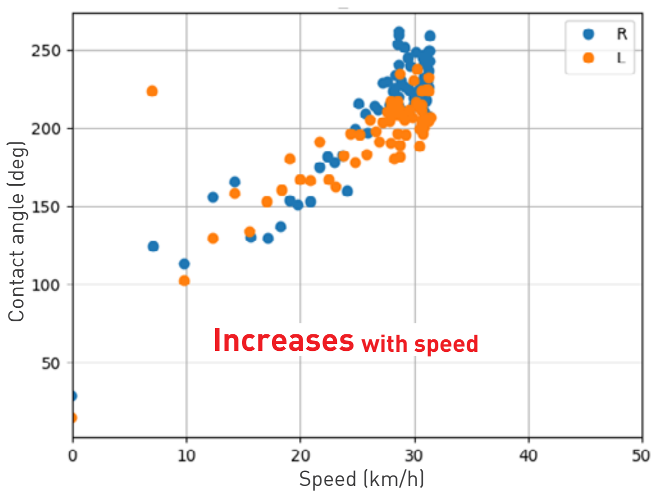
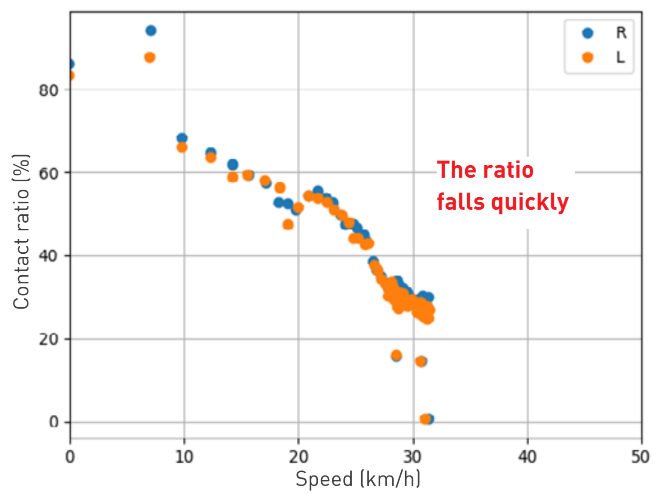
Torque generated at 200 deg is around 5 Nm

Torque is not as high in the narrow wheelchair when pushing through to 200 deg, perhaps because the sides of the athlete's torso collide with the fenders.

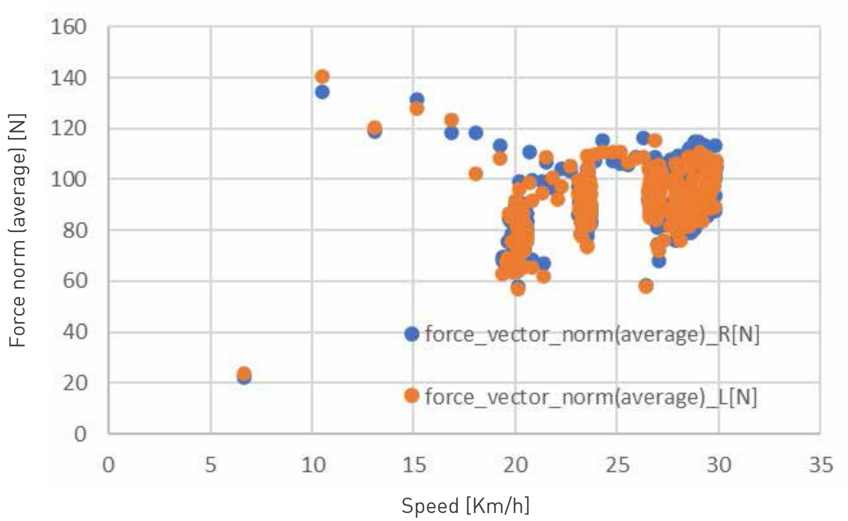
Analysis Examples

(2) Analysis Using CSV Files

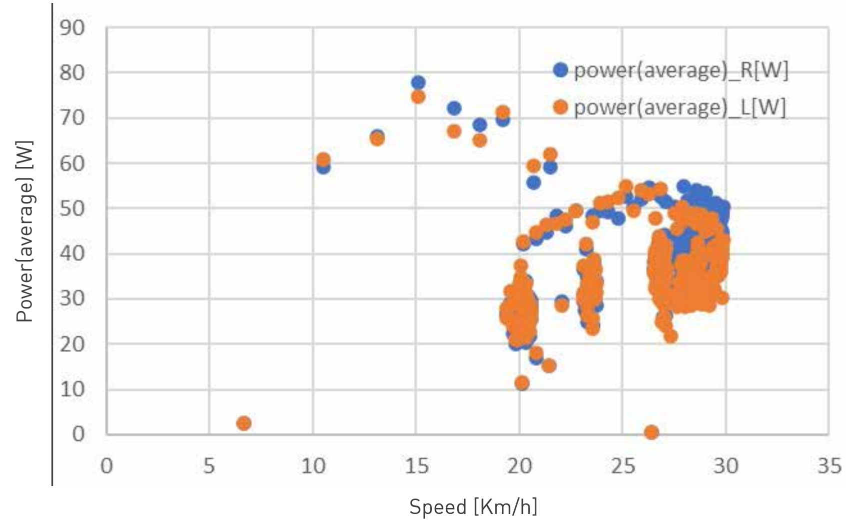
Example: Identify Athlete Types

<table>
<tr><th></th><th>Contact angle (deg)</th><th>Contact ratio (%)</th><th></th></tr>
<tr><td>Athlete
A</td><td>
</td><td>
</td><td>This athlete speeds up by increasing pitch without altering their form (high-cadence propulsion style)</td></tr>
<tr><td>Athlete
B</td><td>
</td><td>
</td><td>This athlete speeds up by increasing the contact angle (long-stroke propulsion style)</td></tr>
</table>

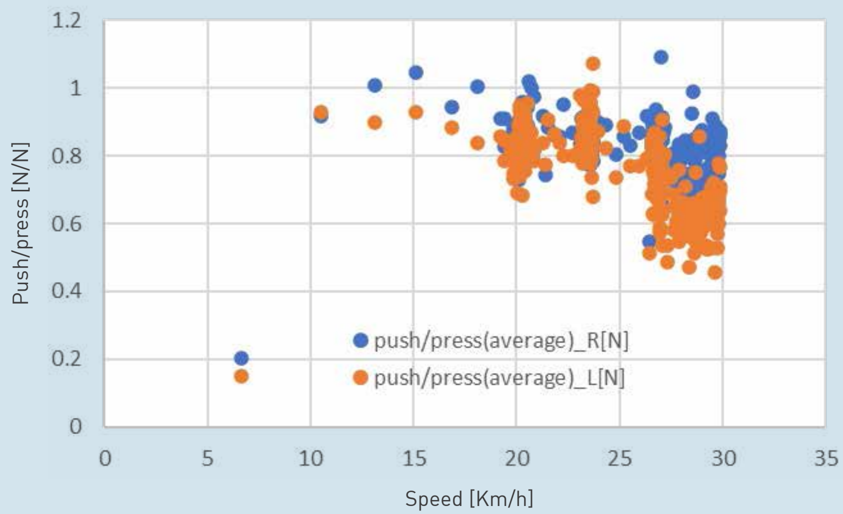
Example: Examine Force, Power, and Push/Press



No divergence of force magnitude between left and right sides even as speed increases



But...power, which is directly linked to acceleration characteristics, falls on the left side.



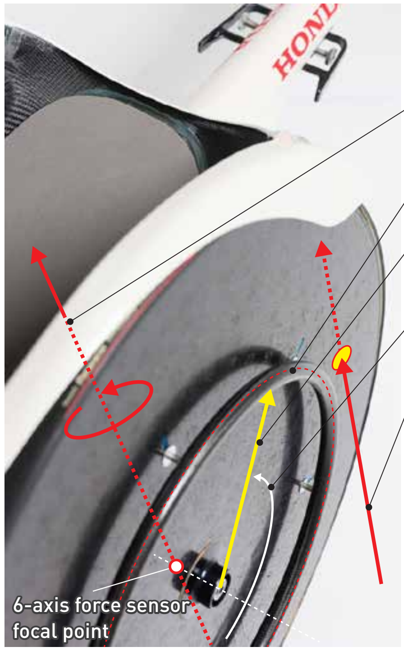
One likely reason for this is that the balance between force directions (push/press) has worsened with speed.

Notes

Computation of Point of Force Application (Two Methods)

*Point of force application (COP) is a physical quantity used for ease of visualization. On uneven surfaces, it can be computed using conditions for approximation.

Computation method "a": Assumes the COP is along the center of the hand ring pipe



$\overrightarrow{{}^{s}M}$ ··············· Propulsion force moment vector in the sensor coordinate system

COP is assumed to be on this circle

$\overrightarrow{{}^{s}\mathrm{cop}({}^{s}\theta_{cop})}$ ··· COP position vector in the sensor coordinate system (function expressed as an angle)

${}^{s}\theta_{cop}$ ··············· COP angular position in the sensor coordinate system

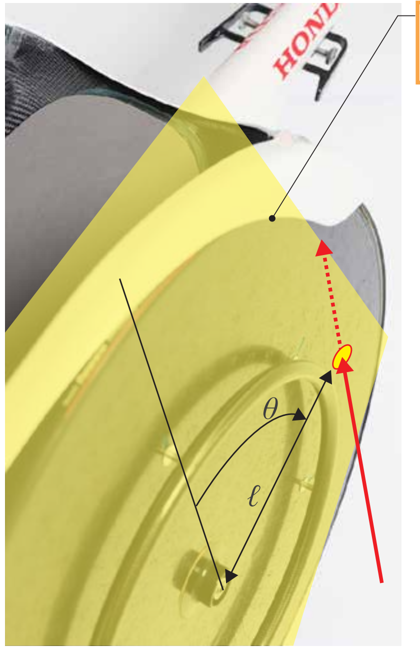
$\overrightarrow{{}^{s}F}$ ··············· Propulsion force vector in the sensor coordinate system

$$\min_{{}^{s}\theta_{cop}} \left| \left(\overrightarrow{{}^{s}\mathrm{cop}({}^{s}\theta_{cop})} \times \overrightarrow{{}^{s}F} \right) - \overrightarrow{{}^{s}M} \right|$$

Determine the COP angle, it being the angle at which the difference between the cross product of the COP position vector and the force vector, and the moment vector is smallest

*This method will produce valid results for some athletes.

Computation method "b": Assumes the COP is on the plane passing through the hand ring



- COP is assumed to be on the plane passing through the center of the hand ring
- Determine COP using the force equilibrium of the 6-axis force sensor

Calculate using a Cartesian coordinate system:

$$x = \frac{h\ F_x - M_y}{F_z}$$

$$y = \frac{h\ F_y - M_x}{F_z}$$

Convert to a polar coordinate system:

$$\ell = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1} \frac{y}{x}$$

*This method will produce valid results for most athletes.