The research story so far: Wheelchair racing as an exemplar
HOW TO PERFORM CLASSIFICATION RESEARCH

Step 1: Identify sport and impairment type(s)

Step 2: Develop model of determinants of sport performance

Step 3a: Develop measures of impairment
Step 3b: Develop measures of (determinants of) performance

Step 4: Assess the impairment-performance relationship

Step 5: Determine minimum impairment criteria and class profiles
HOW TO PERFORM CLASSIFICATION RESEARCH

Step 3a: Develop measures of impairment

Effort Dependence (Intentional Misrepresentation)

Step 4: Assess the impairment-performance relationship

Impact of training
HOW TO PERFORM CLASSIFICATION RESEARCH

Step 1: Identify sport and impairment type(s)

- Athletics
  (Wheelchair racing)
- Muscle strength

Step 2: Develop model of determinants of sport performance

Step 3a: Develop measures of impairment

Step 3b: Develop measures of (determinants of) performance

Step 4: Assess the impairment-performance relationship

Step 5: Determine minimum impairment criteria and class profiles
- Some key muscle groups, positions and actions from published literature and some from expert opinion in Delphi study
Step 3a
Theoretical foundations first....

Measures of impairment
- objective
- reliable,
- Precise
- Ratio scaled
- specific to the impairment of interest
- parsimonious
  (ie, account for the greatest possible variance in sports performance),
- and, as far as possible, be resistant to the effects of training

Reviewed strength assessment literature for best available methods
then protocol development and evaluation

- Relevant to determinants of performance
- Assess reliability
- Assess relationship to body size
- Develop normative values
Wheelchair racing

- Acceleration
- Top speed

- Custom built ergometers
- Athletics Track
Trunk Strength Effect on Track Wheelchair Start: Implications for Classification

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ABSTRACT

VANLANDEWIJCK, Y. C., J. VERELLEN, E. BECKMAN, M. CONNICK, and S. M. TWEEDY. Trunk Strength Effect on Track Wheelchair Start: Implications for Classification. *Med. Sci. Sports Exerc.*, Vol. 43, No. 12, pp. 2344–2351, 2011. Purpose: The T54 wheelchair racing class comprises athletes with normal arm muscle strength and trunk strength ranging from partial to normal. Paralympic sports classes should comprise athletes who have impairments that cause a comparable degree of activity limitation. On the basis of this criterion, the purpose of this study was to determine whether the T54 class is valid by assessing the strength of association between trunk strength and wheelchair acceleration. Methods: Participants were 10 male and 3 female international wheelchair track athletes with normal arm strength. Six were clinically assessed as having normal trunk strength, and seven had impaired trunk strength. Measures included isometric arm and trunk strength and distance covered at 1, 2, and 3 s in an explosive start from standstill on a regulation track, as well as on a custom-built ergometer with four times normal rolling resistance. Results: No significant differences were observed between male athletes with and without full trunk strength in distance covered after 1, 2, and 3 s. Correlations between isometric trunk strength and wheelchair track acceleration were nonsignificant and low (0.27–0.32), accounting for only 7%–10% of variance in performance. Correlations between trunk strength and distance pushed under high resistance were also nonsignificant, although values were almost double (r = 0.41–0.54), accounting for 18%–26% of the variance in performance. Conclusions: These results provide evidence that impairment of trunk strength has minimal effect on wheelchair acceleration and indicate the T54 class is valid. Results do not infer that athletes with no trunk strength should compete with those who have partial or full trunk strength. Key Words: ATHLETICS, ACTIVITY LIMITATION, IMPAIRMENT, PARALYMPIC, RACING

In 2009, the International Paralympic Committee (IPC) endorsed extensive revisions of the IPC Athletics Classification System, which will be implemented after the 2012 London Paralympic Games (10). The stated purpose of the revised system is consistent with the IPC position stand on classification in Paralympic sport—to promote participation in sport by people with disabilities by minimizing the effect of impairment on the outcome of competition (10,11).
Cluster analysis of novel isometric strength measures produces a valid and evidence-based classification structure for wheelchair track racing

Mark J Connick,1 Emma Beckman,1 Yves Vanlandewijck,2 Laurie A Malone,3 Sven Blomqvist,4 Sean M Tweedy1

ABSTRACT
Background The Para athletics wheelchair-racing classification system employs best practice to ensure that classes comprise athletes whose impairments cause a comparable degree of activity limitation. However, decision-making is largely subjective and scientific evidence which reduces this subjectivity is required.

Aim To evaluate whether isometric strength tests were valid for the purposes of classifying wheelchair racers and whether cluster analysis of the strength measures produced a valid classification structure.

Methods Thirty-two international level, male wheelchair racers from classes T51–54 completed six isometric strength tests evaluating elbow extensors, shoulder flexors, trunk flexors and forearm pronators and two wheelchair performance tests—Top-Speed (0–15 m) and Top-Speed (absolute). Strength tests significantly correlated with wheelchair performance were included in a cluster analysis and the validity of the resulting clusters was assessed.

Results All six strength tests correlated with performance (r=0.54–0.88). Cluster analysis yielded four clusters with reasonable overall structure (mean silhouette coefficient=0.58) and large intercluster strength differences. Six athletes (19%) were allocated to clusters that did not align with their current class. While the para-athletes’ unique performance of the

The purpose of these classes is to control for the impact of impairment on the outcome of wheelchair track races, so that the athletes who succeed will be those with the most advantageous combination of physiological, psychological and anthropometric attributes.1 Conceptually, this requires classes that each comprise athletes with impairments that cause a similar degree of activity limitation in wheelchair racing. Accordingly, class profiles reflect a logical hierarchy (table 1). Class T51 is for athletes with impairments causing the greatest activity limitation. These athletes typically have significant strength impairments in all of the muscle groups required for optimal wheelchair propulsion, these being the shoulder flexors/adductors, the elbow extensors,2 wrist pronators2 and possibly the trunk flexors.2 The hierarchy progresses to T54 in which impairments result in minimal activity limitation in wheelchair racing (eg, below knee amputation or L4 SCI).

Class allocation for athletes with a motor-complete SCI is relatively straightforward because their impairment profile will be an exact match for one of the class profiles in table 1. However, an increasing number of athletes have impairment profiles which are not an exact match for any one profile, such as impairment profiles resulting from motor-incom-
<table>
<thead>
<tr>
<th>Isometric strength measure</th>
<th>Performance Outcome</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top-Speed (0-15m)</td>
<td>Top-Speed (Absolute)</td>
</tr>
<tr>
<td></td>
<td>correlation</td>
<td>correlation</td>
</tr>
<tr>
<td>Strongest Forearm Pronation</td>
<td>0.70*</td>
<td>0.79*</td>
</tr>
<tr>
<td>Weakest Forearm Pronation</td>
<td>0.70*</td>
<td>0.79*</td>
</tr>
<tr>
<td>Strongest Arm Extension</td>
<td>0.83*</td>
<td>0.88*</td>
</tr>
<tr>
<td>Weakest Arm Extension</td>
<td>0.81*</td>
<td>0.87*</td>
</tr>
<tr>
<td>Isolated Trunk</td>
<td>0.54*</td>
<td>0.61*</td>
</tr>
<tr>
<td>Arm+Trunk</td>
<td>0.73*</td>
<td>0.78*</td>
</tr>
</tbody>
</table>

Step 5: Determine minimum impairment criteria and class profiles
Results: Silhouette analysis of k-means cluster outcomes and current classes

- Silhouette analysis for k-means clusters was superior to the current classes

<table>
<thead>
<tr>
<th>k-means clusters</th>
<th>Current classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Silhouette coefficient = 0.58 (good)</td>
<td>Mean Silhouette coefficient = 0.32 (weak)</td>
</tr>
</tbody>
</table>

![Graph showing k-means clusters and current classes with silhouette values and counts for each cluster.](image-url)
What next?

Implementation?
Responsibility?
What else?

- Based at the Australian Institute of Sport

“Towards evidence-based classification for runners with brain impairment in World Para Athletics”
HOW TO PERFORM CLASSIFICATION RESEARCH

Step 3a: Develop measures of impairment

Effort Dependence (Intentional Misrepresentation)

Step 4: Assess the impairment-performance relationship

Impact of training
Intentional Misrepresentation

PhD Topic – Developing methods for detecting Intentional Misrepresentation in Strength testing
HOW TO PERFORM CLASSIFICATION RESEARCH

Step 3a: Develop measures of impairment

Effort Dependence (Intentional Misrepresentation)

Step 4: Assess the impairment-performance relationship

Impact of training
Impact of training on measures

Do measures of impairment developed for the purposes of classifying Para swimmers change in response to performance focused swimming training?
Training load

![Graph showing training load over weeks with RPE minutes on the y-axis and weeks on the x-axis. The graph displays fluctuations in training load throughout the weeks.]
3RM Chest press
Dynamic Strength

Right upper limb isometric strength
Impairment Specific training assessment tests

<table>
<thead>
<tr>
<th>Movement Characteristic</th>
<th>Criterion Activity</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Running</td>
<td>Sidestep Test</td>
</tr>
<tr>
<td>Static balance</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dynamic balance</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Active range of movement</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lower limb coordination</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Power</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Symmetry</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Whole body coordination</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 3 Relationship between the criterion activity limitation test (30 m sprint) and tests of activity limitation (n = 67)

<table>
<thead>
<tr>
<th>Correlation with sprint performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running in place</td>
</tr>
<tr>
<td>10 m skip</td>
</tr>
<tr>
<td>Split jumps</td>
</tr>
<tr>
<td>Standing broad jump (adjusted)</td>
</tr>
<tr>
<td>Four bounds (adjusted)</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed).

These tests have been introduced into WPA classification for runners with Brain Impairments as of 2019. All athletes classified must undergo these tests

Impairment  ISTATS  Performance
Impairment Specific training assessment tests

1. Strength data
2. Class (vec)
3. Class (mat)

Load ISTATs

RECOMMENDED CLASS

3

1. St.Pronation (N) 130
2. We.Pronation (N) 120
3. Isol.Trunk (N) 290
4. St.Push (N) 450
5. We.Push (N) 360
6. Tr+Arm (N) 410

3. Predict class

Predicted Class:

LDA 3
ANN 3
k-NN 4

Probability class 1:

0
0
0

Probability class 2:

0
0
0

Probability class 3:

0.54
1
0.45

Probability class 4:

0.45
0
0.55

4. Regress strength on ISTAT

Enter ISTAT outcome:

Predicted ISTAT:

Lower prediction interval:

Update

Panel

2
4
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Thank you