Classification of strength impairments in wheelchair athletes using cluster analysis

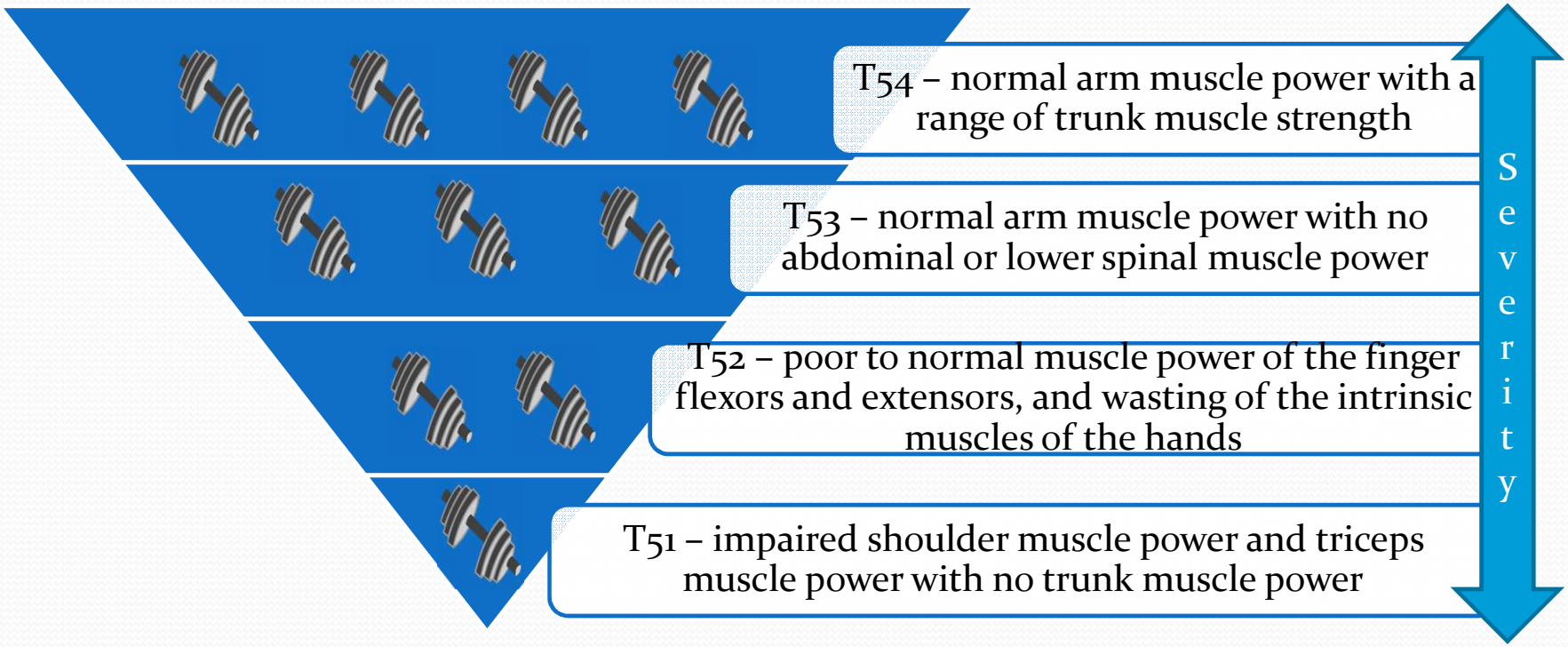
Mark J. Connick[1]; Emma M. Beckman[1]; Yves Vanlandewijck[2]; Laurie A. Malone[3]; Sven Blomqvist[4]; Sean M. Tweedy[1]

AFFILIATIONS: [1]School of Human Movement and Nutrition Sciences, University of Queensland, Brisbane, Australia; [2]Faculty of Kinesiology and Rehabilitation Sciences, Katholieke Universiteit Leuven, Belgium; [3]Lakeshore Foundation, Birmingham, AL, USA; [4]Faculty of Health and Occupational Studies, University of Gävle, Sweden

Acknowledgements

- This work was made possible through support of:
  - Zayed Higher Organisation for Humanitarian Care and Special Needs
  - International Paralympic Committee
  - Australian Research Council (LP0882187)

Classification profiles – wheelchair track events



Case: Person with C6 incomplete who has some trunk function but arms are also affected (i.e., less strength in arms than T53, but more strength in trunk).

Incomplete cord injuries – same impairment type but different pattern

Key Question: Is the disadvantage caused by lower arm strength greater than the advantage given by increased trunk strength?

Possible outcomes:

T52: disadvantage of arm weakness is more than advantage of trunk

T53: disadvantage of arm weakness is equal to advantage of trunk

T54: disadvantage of arm weakness is less than advantage of trunk

Current best practice for assigning class

Assess strength impairment

+

Athletic History

Sports-specific motor tasks

= Class Allocation

Assessing strength impairment for wheelchair racing classification - current

- Manual muscle testing (Daniels and Worthingham, 2002)
- 6 point scale, from 0 to 5
  - 5: normal muscle power through available ROM
  - 4: active movement through available ROM, against gravity plus some resistance
  - 3: active movement through full available ROM against gravity but no resistance
  - 2: active movement with gravity eliminated (some movement against gravity may be possible but not full range)
  - 1: trace muscle activity but no movement of the limb
  - 0: no muscle activity

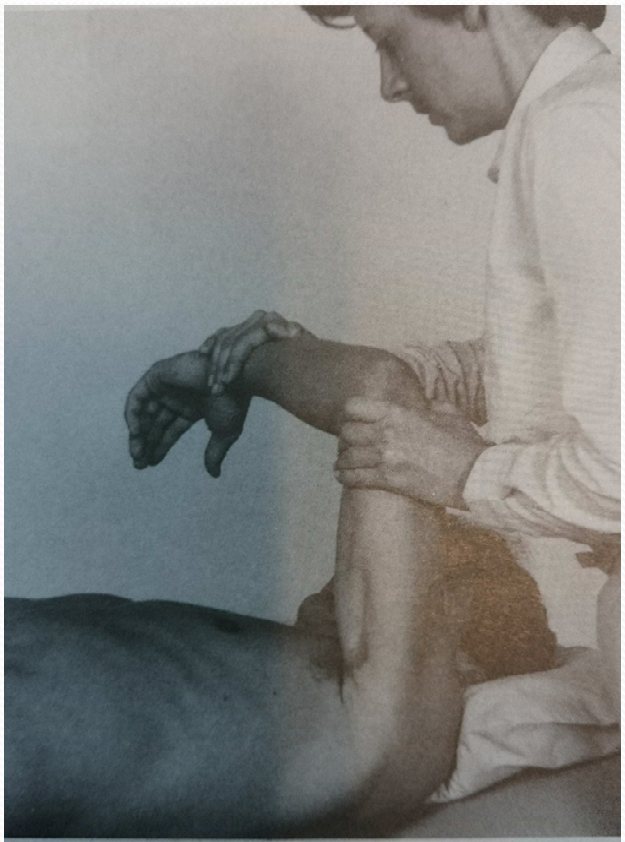


Figure 4.34. Resistance: triceps.

Aims

- to evaluate the validity of ratio-scaled and precise strength measures for the purposes of classifying impairments in Paralympic athletes with impaired muscle power

- to identify distinct groups of athletes in our sample using a cluster analysis of the muscle strength data

Methods

- Participants: 32 male International track athletes with confirmed IPC Athletics wheelchair racing classifications (T54 to T51 classes)
  - T54(n=14), T53(n=7), T52(n=6), T51(n=5)
  - Range of health conditions (self-reported): spinal cord injury (incomplete and complete), amputees, polio, spina bifida, arthrogryposis, caudal regression syndrome
- Measures:
- Strength : 6 measures of isometric strength obtained using S-type load cell mounted in rigid, custom-built rig:
  - Pronation strength (left and right)
  - Composite single-arm push strength (left and right)
  - Isolated trunk strength
  - Composite arms+trunk strength
- Performance measures: peak velocity in a sprint start (om to 15m) (PVSS) and maximum achievable velocity (MAV) were measured.
- Statistical Analysis
  - Pearson's correlation coefficients were used to evaluate strength of relationship between strength and performance measures
  - The gap statistic was used to identify the number of classes and k-means cluster analysis to allocate class
  - Validity of the classes was evaluated by comparing effect sizes and silhouettes in the clustered classe and the current classes

Custom-built strength rig and Strength Tests

Composite single-arm push strength

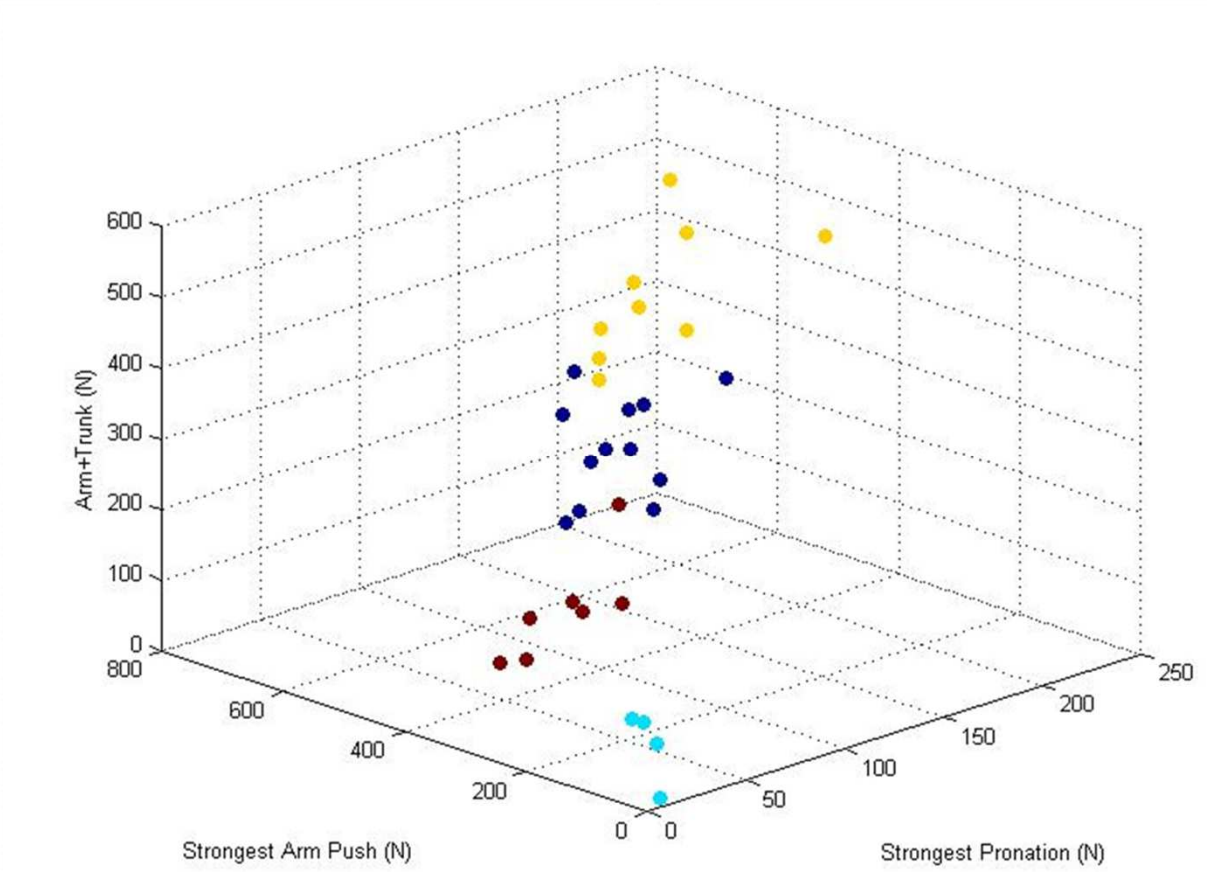
Arm+Trunk Strength

Beckman, E.M., Newcombe, P., Vanlandewijck, Y.C., Connick, M.J., and Tweedy, S.M., (2014) Novel Strength Battery to Permit Evidence-based Paralympic Classification, Medicine, 93(4), e31

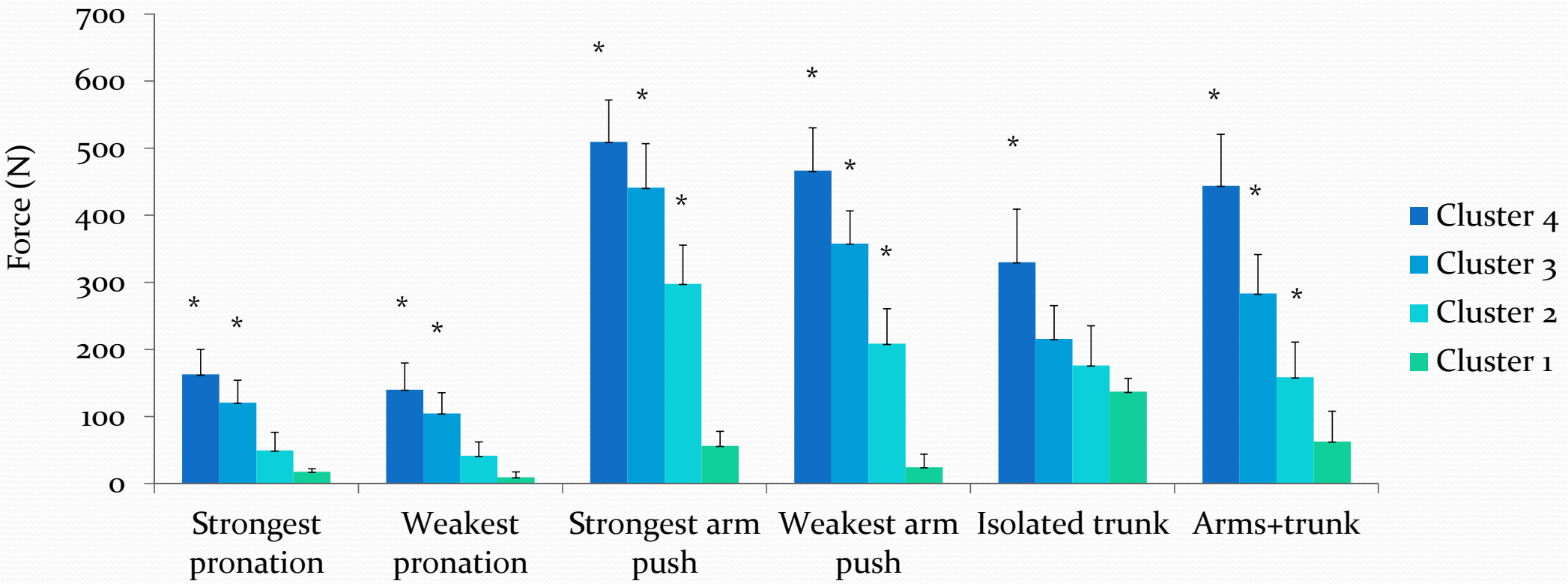
Results

- All strength measures tested in this study significantly correlated with both measures of wheelchair sprint performance (Pearson's Correlation Coefficient average = 0.75)

- The Gap statistic indicated that a 4 class structure was optimal



Results: Mean strength by k-means cluster

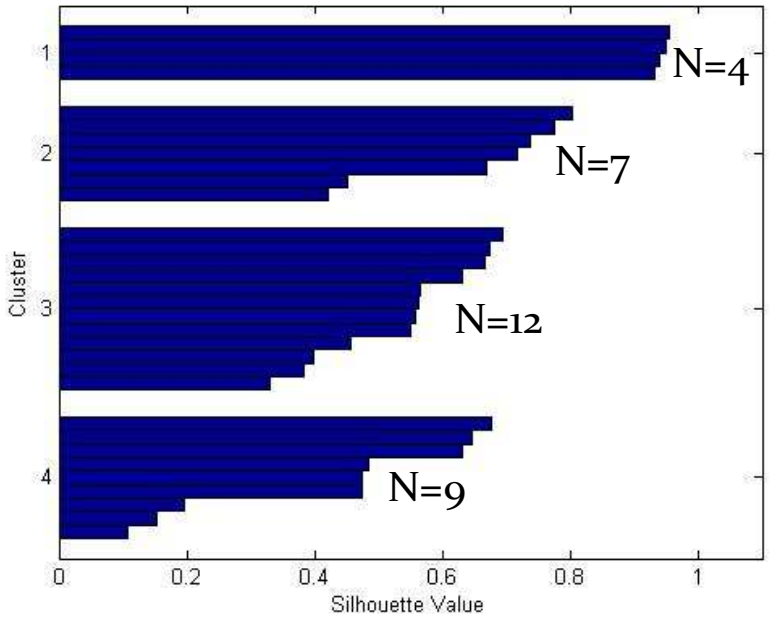


Results: Silhouette analysis of k-means cluster outcomes and current classes

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

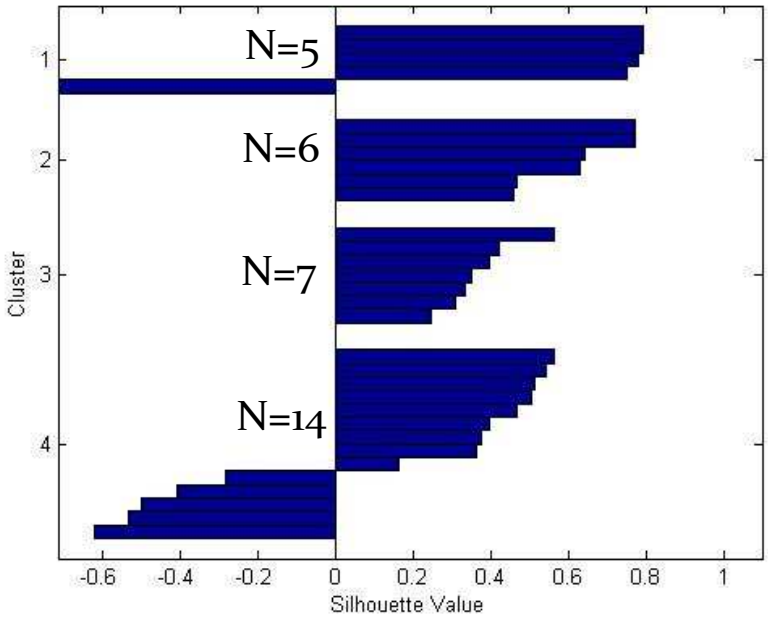
k-means clusters

Mean Silhouette coefficient = 0.58 (good)



Current classes

Mean Silhouette coefficient = 0.32 (weak)



Results: Between-cluster effect size vs between class effect size

- Why are effect size important?
- Cluster vs. current classes
- Were all tests practically useful?

Interclass comparison	Outcome Measure								
	Strongest Pronation	Weakest Pronation	Strongest Arm	Weakest Arm	Isolated trunk	Arm+Trunk	Acceleration	Top Speed	Mean
Cluster4 vs Cluster 3	1.2	1.0	1.1	1.9	1.7	2.4	0.9	1.4	1.2
T54 vs T53	0.9	1.1	0.7	0.8	2.1	1.4	0.3	0.9	0.9
Cluster 3 vs Cluster 2	2.4	2.4	2.3	3.0	0.7	2.3	1.6	2.1	2.1
T53 vs T52	2.3	2.5	1.8	2.7	0.2	2.1	1.4	1.7	1.8
Cluster 2 vs Cluster 1	1.6	2.1	5.5	4.7	0.9	2.0	1.6	2.5	2.3
T52 vs T51	1.7	1.9	3.5	2.0	0.5	0.9	1.6	2.0	1.5

Discussion

- Validity of our 6 novel isometric strength measures indicated by moderate to strong correlation between the measures and wheelchair performance;
- Gap-statistic analysis supported the current practice of dividing wheelchair racing athletes into four classes but:
  - the composition of the clusters that were based on k-means analysis of the strength measures was different to the composition of the current classes;
  - Silhouette analysis indicated the k-means class structure was stronger than the current class system
  - Compared with current classes, there were greater differences between the performances of each of the k-means clusters, indicating better face validity

Discussion cont'd

- Clusters in this study were consistent with neurological profiles for the current class system, that is:

Strength test	Principal muscle actions/s (segmental innervation)	Largest between-group difference (effect size)	Equivalent current class and segmental level
Composite arm strength	Shoulder flexion and elbow extension (C5-8)	Cluster 1 vs 2 (5.5)	T51 (C5-6) vs T52 (C7-8)
Pronation	Pronation (C7-8)	Cluster 2 vs 3 (2.4)	T52 (C7-8) vs T53 (T1-6)
Isolated trunk	Trunk flexion (T7-T12)	Cluster 3 vs 4 (1.7)	T53 (T1-6) vs T54 (T7 and below)

- Outcomes from this study warrant development of a responsible, conservative translational plan in partnership with IPC Athletics

Thank you and Hasta la VISTA