Article
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Adaptive Sports/Recreation Topic Categories
- Classification
- Sports/Physical Activity Performance
- Para football

Research Questions
- What are the sensitivities of several tests of stability, dynamic balance, coordination, range of movement, and lower limb power that are used to discriminate between the impaired and unimpaired lower extremities' function in para-athletes with spastic hemiplegia?
- How can this data help cluster these para-athletes according to their functionality/performance level?

Methodology
- Participants were para-athletes selected to be part of the international cerebral palsy football squad. All participants had cerebral palsy (CP) or related neurological conditions that provoke mild or moderate spastic hemiplegia, and all were classified as level I on the Gross Motor Function Classification System.
- Measures: Six tests were conducted to measure various abilities:
    - Range of movement with the backward stepping lunge (BSL).
    - Lower limb strength – peak of force – by an isometric measurement of knee extensors (PF).
    - Coordination with rapid heel-toe placements (RHT).
    - Dynamic balance with the side-step test (SS).
    - A combination of impaired power intra-limb coordination and stability – the triple-hop for distance field test (TH).
    - Static balance with the one-leg stance (OLS) test, measured as magnitude of mean velocity (VMM).
- Protocol:
    - Data collected in an intercontinental tournament to qualify for the CP Football World Championships.
    - Two trials conducted per leg, best score used for analysis.
    - Every test administered by the same researcher for consistency.
    - Both legs tested; unimpaired side tested first.
    - Recorded variables categorized as impaired or unimpaired. Difference of performance between legs was calculated.
- Test sensitivities were compared used the Boruta method; goal was to rank the tests according to their importance in determining the para-athletes' impaired side.
- Participants were clustered according to differences in their performance in each test.
- A classification clustering model was built to predict the impaired side using the results of the most sensitive tests; this clustering was compared to the two original sports classes (FT7 and FT8).

Results
- Eighty-seven international male football para-athletes (Age = 25.8 + 6.7 yr; Body mass = 69.2 + 8.6 kg ; Height = 1.75 + 0.7 m) with CP or related neurological conditions with associated spasticity participated in this study.
    - Participants had a profile of moderate (FT7 = 74) or mild (FT8 = 13) spastic hemiplegia.
    - 10 countries represented from Europe, North America, and South America.
- Ranking of the tests in terms of effectiveness for determining the impaired side:
    - Most relevant: triple-hop for distance field test (TH).
    - High sensitivity: magnitude of mean velocity (VMM) on one-leg stance (OLS) test and rapid heel-toe placements (RHT).
    - Low sensitivity: side-step test (SS).
    - Irrelevant: peak of force (PF) and backward stepping lunge (BSL) tests.
- Classification clustering model was built using the results of the most sensitive tests (TH and VMM in the OLS); results were compared to original sports classes (FT7 and FT8).
    - Model suggested 41% of para-athletes did not align with current sport class.

Discussion/Conclusion
- TH was the best test for discriminating between impaired and unimpaired leg function; test assesses strength and power capacity of the lower limbs along with intersegmental coordination and stability.
- Additionally, VMM was effective in assessing stability and RHT was effective in assessing coordination.
- Cluster analyses were able to find clear distinction among the performance levels of para-athletes according to the tests applied, but there was a 41% mismatch when compared to current sport classification.

Article Strengths
- This study incorporates six tests assessing various dimensions of athletic performance in order to explore performance asymmetries in para-athletes with spastic hemiplegia.
- This study highlights three relevant and sensitive functional tests to improve assessment of football para-athletes with spastic hemiplegia, and this data may guide decision-making in future Paralympic classification.
- Reference scores for these assessments are also provided to cluster para-athletes with spastic hemiplegia.

Article Weaknesses
- Applicability limited to international level CP football para-athletes with spastic hemiplegia.
- Performance on these assessments was not correlated with other standard measurements of spasticity (e.g. Modified Ashworth Scale or Australian Spasticity Assessment Scale).
- Some assessments (e.g. center of pressure velocity) require expensive equipment that may limit their use.
- Discussion of statistics and clustering methodology was difficult to follow.
- Four participants were omitted from the results without explanation.

- Specific testing methods are not currently described in supplementary material, limiting reproducibility.

Take Home Messages
- Current para-football assessment and classifications may suboptimal.
- Coordination, balance, and power of the lower limbs are relevant variables for classifying para-athletes with spastic hemiplegia.
- These assessments can be used to create clustering models that may enhance the classification system for para-footballers with spastic hemiplegia currently competing in FT7 and FT8 sport classes.
- This data may help other para sports apply scientific methods to more objectively classify para-athletes with spastic hemiplegia.