Introduction and objective

Therapy success is assumed when there is no evidence of disease activity, and especially no evidence of disability progression. Gait analysis plays a major role as gait impairment is considered by patients as the most disabling symptom [1]. Monitoring this phenomenon is thus important in the clinical setting. But how should we do this? By selecting an appropriate technology, it is possible to measure many spatiotemporal gait parameters, describing both the swing and stance phases, even during long tests (e.g. 6min, 500m), without equipping patients with markers or sensors. Comfortable (at self selected speed), as fast as possible, and heel-to-toe (tandem) walking are typical tests. In this work, we determine if there is an advantage to perform various walking tests (in a reasonable amount of acquisition time), and which test or combination of tests is the most informative about the patient state. We focus on the ability to make objective decisions based on the measured gait parameters.

Method

- Many healthy volunteers (469 visits) and MS patients (86 visits) performed 12 tests:
  - comfortable on a straight path of 25 ft (7.62 m)
  - comfortable on a straight path of 25 ft (second try)
  - as fast as possible on a straight path of 25 ft
  - as fast as possible on a straight path of 25 ft (second try)
  - tandem on a straight path of 25 ft
  - tandem on a straight path of 25 ft (second try)
  - comfortable on a ∞-shaped path of 20 m
  - as fast as possible on a ∞-shaped path of 20 m
  - as fast as possible on a ∞-shaped path of 100 m (5 laps of 20 m)
  - as fast as possible on a ∞-shaped path of 100 m (5 laps of 20 m)
  - as fast as possible on a ∞-shaped path of 500 m (25 laps of 20 m)
  - All tests were recorded and analyzed with a gait measuring system GAIMS [2, 3, 4]. 20 gait parameters were computed for each test, and normalized with respect to those of healthy people with the same morphological characteristics (weight, height, age, gender, shoesize) as in [5].

- To assess the ability to detect disability progression based on these clinical outcome measures, we evaluate the possibility of differentiating the people below a given EDSS threshold (0.75) from those above it based only on the gait measured parameters. We measure (by leave-one-person-out) the performance of the 12 classifiers learned automatically with the machine learning technique named ExtraTrees (a forest of decision trees) [6]. They predict the probability of MS given the gait characteristics, and we apply a correction to express them with respect to a prior of $1/2$.

- As the classifiers are poorly correlated, we expect some benefits by combining them. Thus, we study the performance that can be achieved by combining the decisions of the 12 classifiers, in all subset of them. We assume that the optimal walking tests to assess disability progression are those leading to the best performance. Four combination strategies are analyzed: the probabilistic product [7], the median (related to a majority vote), the mean, and a weighted average (we determined the weights using a linear support vector machine with a soft margin and controlling its hyper-parameter C to avoid over-fitting and negative weights).

- The ability to detect the disability progression is quantified by the area under the ROC curve (AUC) and the maximum achievable balanced accuracy (MBA) of the combination. We show these metrics for each possible subset of tests, with respect to the total walking distance.

Conclusions

- With an appropriate measuring system, the clinical gait analysis can help to detect disability progression.
- Despite they are considered as standardized, the shortest (25 ft) walking tests are the worst when considered alone, while the longest (100 m, 500 m) ones are the best.
- Considering different walking tests improves the ability to take decisions, but the tests should be carefully selected. Considering more tests than necessary can deteriorate the usefulness of clinical gait analysis.
- We have studied 1727 sets of tests. Our advice is to consider 4 tests for a total walking distance of 55.24 m only: two 25 ft walked as fast as possible, one 20 m with a comfortable pace on a ∞-shaped path, and one 20 m in tandem gait.

References


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