Journal of Physiotherapy 64 (2018) 200–201

AUSTRALIAN PHYSIOTHERAPY ASSOCIATION

Journal of PHYSIOTHERAPY

journal homepage: www.elsevier.com/locate/jphys

Appraisal

Correspondence: Time-based versus repetition-based sit-to-stand measures: choice of metrics matters

In both healthy and clinical older populations,[1–4] the sit-to-stand (STS) test is a common and popular test of functional performance. STS performance is quantified by two metrics: time-based STS metric is the time taken to complete a specified number of STS repetitions; repetition-based STS metric is the number of STS repetitions completed in a specified period of time. Physiologically, when the specified number of STS repetitions is low ($<$ 10 repetitions) and the specified period of time is short ($<$30 seconds), both time-based and repetition-based STS metrics assess lower extremity muscle strength and give relatively the same information.[3] Mathematically, time-based and repetition-based STS metrics are equivalent: less time taken to perform one STS repetition equates to more repetitions completed in a specified period of time. However, the association is not linear because one metric is the inverse of the other:

$$\left(Time\ \ metric = \frac{Specified\ \ repetition\ \ number}{Repetition\ \ metric} \right).$$

This nonlinear association (graphically shown in Figure 1) has research and clinical implications that are not well reported or studied. These are described below.

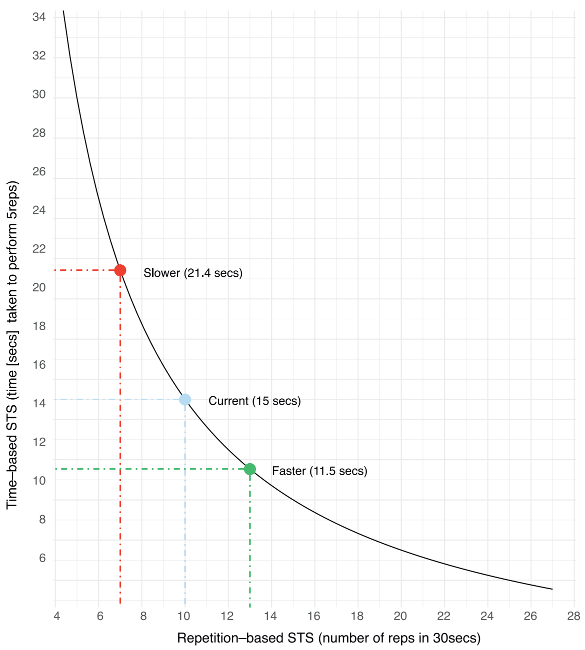

Figure 1. Time-based sit-to-stand (STS) metric is a nonlinear function of repetition-based metric. In 30 seconds, increasing the number of STS repetitions performed from 7 to 10 improves the corresponding five times-STS performance by ~6.4 seconds (from 21.4 to 15 seconds). However, increasing the number of STS repetitions from 10 to 13 only improves the corresponding five times-STS performance by ~3.5 seconds. This figure was generated from https://sgh-physio.shinyapps.io/STSmetrics/

Research implications

Given that test-retest errors in repetition-based STS metric are reportedly homoscedastic,[2] the nonlinear association suggests that the corresponding test-retest errors in time-based metric are heteroscedastic. The intuition here is that if the repetition-based STS measures fluctuated at a constant level, the corresponding fluctuations on the time scale would increase at decreasing values on the repetition-based metric. To illustrate this point, we generated a simulated dataset for both test and retest repetition-based STS data which, by design, showed no systematic bias and heteroscedasticity. However, heteroscedasticity appeared when the repetition-based metric was converted into time-based metric (Figure 2). Reviewing the literature, one study reported heteroscedasticity in the time-based STS metric but postulated only biological reasons for the findings.[5] Among studies that did not rigorously test for data heteroscedasticity, three studies reported greater reliability in repetition-based than in time-based STS metric.[6–8] Another study reported improved absolute reliability for the time-based metric when participants performed the STS test more rapidly.[9] If data

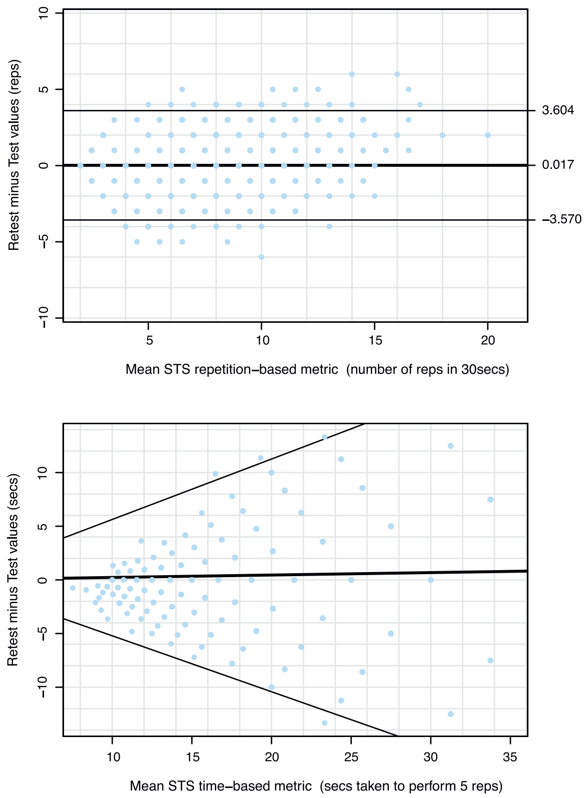

Figure 2. Bland–Altman plots showing the 95% limits of agreement for the simulated homoscedastic sit-to-stand (STS) repetition-based data (top panel) and the corresponding heteroscedastic STS time-based data (bottom panel). This figure was generated from https://sgh-physio.shinyapps.io/STSmetrics/

https://doi.org/10.1016/j.jphys.2018.05.010

heteroscedasticity in the time-based metric were present but not accounted for, (spuriously) large absolute errors could arise.

Clinical implications

At the individual level, to detect important improvement or deterioration in STS performance, if the minimal clinically important difference on the repetition-based metric is a constant,[2] the corresponding change scores on the time-based metric are non-constant and asymmetrical (Figure 1). With this asymmetry, patients may appear to be getting decreasing returns when they improve the time-based metric but constant returns when they improve the repetition-based metric. Thus, it is logical to speculate that patients may be more motivated to improve their STS performance on a repetition-based metric. To our knowledge, no clinical studies have examined this intriguing question; however, emerging research in business management[10,11] has shown that the choice of different – but equivalent – performance metrics can influence employee motivation.

In conclusion, while we have focused on the STS test, the implications that we have described may apply to other time-based and rate-based physical performance measures. A web application, available at https://sgh-physio.shinyapps.io/STSmetrics/, allows readers to: simulate test-retest STS data; visualise the nonlinear associations between time-based and repetition-based STS metrics; and convert minimal clinically important difference values on the repetition metric into equivalent values on the time metric. It is hoped that this web application and letter will stimulate 'nonlinear thinking' in readers and help them to make better decisions.

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