QUANTIFICATION OF TIME TO STABILISATION USING THE SEQUENTIAL ESTIMATION TECHNIQUE

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**KEYWORDS:** time to stabilisation, dynamic balance, ground reaction force

INTRODUCTION: Dynamic postural stability is a key physical attribute for athletes and can be defined as the ability to maintain postural balance whilst moving from a dynamic to a static state (Wikstrom et al., 2005). This dynamic stability requires the complex integration of sensory afferent systems (visual, somatosensory and vestibular) with efferent responses in both upper and lower body neuromuscular systems. The effect of neuromuscular pathologies on dynamic postural stability has been the focus of a considerable body of research (e.g. Ross et al. 2009), particularly in the areas of chronic ankle instability and ACL injury. Underpinning this research are several functional tests that have been proposed to objectively quantify dynamic postural stability. One of the most commonly cited measures from these tests is known as 'time to stabilisation' (TTS) which is defined as the time required to reach stability after landing. As reaching stability is a somewhat non-specific event, several different techniques have been proposed for quantifying the TTS. The majority of techniques use a generalised approach that identifies when the resultant ground reaction forces (GRFs) reach some baseline threshold. One such TTS technique was proposed by Colby et al. (1999) and has since been used by numerous others (e.g. Shaw et al. 2008). This technique uses a process called sequential estimation, whereby a cumulative average of GRF data is calculated by adding one data point at a time. Stabilisation is deemed to occur when the cumulative average reaches and stays within 0.25 SDs of the overall mean. This sequential estimation procedure has been applied to mediolateral (M-L), anterior-posterior (A-P) and vertical GRF data from a range of jump types. While data from this technique has not always supported expected group or condition differences in stability, the technique is still well recognised and used in TTS calculation.

To the author's knowledge, no research has pointed to mechanistic flaws in the use of sequential estimation in calculating TTS values. However, on reviewing the technique, it appears that the use of both the cumulative average and SD values predispose the technique to inaccurate TTS assessments. Use of a cumulative average suggests that increased force oscillations can theoretically reduce the TTS, and similarly, the use of SD values based on the full landing sequence implies that the threshold range is larger for less stable landings and can thus also theoretically lead to shorter TTS values. In seeking to understand the links between dynamic stability and neuromuscular pathologies, it is clearly essential that the measures used are robust and do not provide spurious results. Therefore, the aim of this paper was to assess the validity concerns of the sequential estimation method of TTS calculation by using it to compare jumps with clear differences in dynamic stability.

METHOD: A healthy male subject (age 29 years, mass 89.5 kg, leg length 95.5 cm) completed 10 hop trials in each of two conditions. In condition one (stable), their goal was to stabilise as quickly as possible after landing and hold the stable posture for a further three seconds. In condition two (unstable), they were asked not to stabilise immediately on landing but to continue swaying in the A-P plane on one leg. Condition two was used to simulate poor dynamic stability. The hops were conducted in accordance with the protocol used by Colby et al. (1999), and in brief involved a single-legged forwards hop and landing onto the force plate from a distance of one leg length. Data from a piezoelectric force plate (Kistler AG, Winterthur, Switzerland) were recorded in A-P, M-L and vertical planes at 1000 Hz for 3 seconds after impact (force > 5 N). TTS values were calculated using the sequential estimation approach presented by Colby et al. (1999) for GRF data in all three planes for all

20 hops. Differences between TTS scores for each condition were assessed for statistical significance using an independent samples t-test in SPSS (v.17) with an alpha level of 0.05.

RESULTS AND DISCUSSION: Qualitatively, clear differences were evident between force traces for unstable and stable landings (see Figure 1), which supported the correct execution of both landing conditions. However, vertical force TTS values were significantly shorter ($p=.005$) in unstable landings than stable landings (see table 1 for mean TTS scores). This indicates particularly poor validity for this method of TTS assessment as unstable landings should actually show longer TTS values. No significant differences were shown for A-P and M-L TTS values between the conditions ($p=0.30$ and 0.20, respectively). The sequential estimation technique may hold an advantage over other methods of TTS assessment as its protocol is clearly documented and can be carried out easily in MS Excel, however, the data from this study shows that it cannot even differentiate correctly between extreme conditions of stable and unstable landings, and in fact portrays the unstable landings as being the most stable when considering TTS of vertical GRFs.
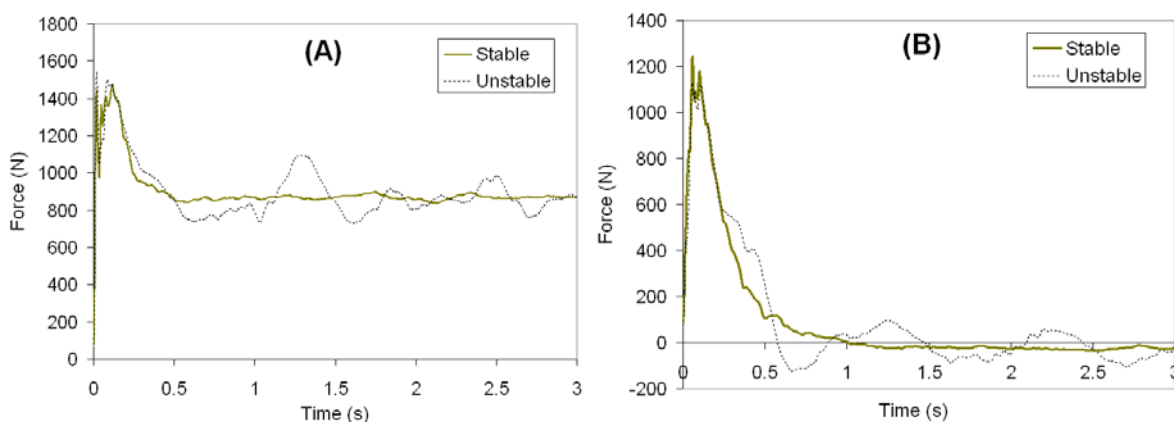
Figure 1. (A) Exemplar vertical force traces for stable and unstable landings, where stable TTS = 1.44s and unstable TTS = 1.03s. (B) Exemplar A-P force traces for stable and unstable landings, where stable TTS = 1.80s and unstable TTS = 1.78s.

Table 1. TTS scores (mean±SD) for stable and unstable landings using sequential estimation

	Vertical TTS (s)	Anterior-Posterior TTS (s)	Mediolateral TTS (s)
Stable	1.44 ± 0.03	1.79 ± 0.02	0.58 ± 0.44
Unstable	1.18 ± 0.17	1.80 ± 0.04	0.88 ± 0.54

CONCLUSION: The results of this study question the validity of the sequential estimation technique for calculating TTS with A-P, M-L or vertical GRF data. Practitioners and researchers with an interest in dynamic stability should note the presented limitations of this technique when reviewing literature or planning future studies in the area.

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