Normalization of Timed Up and Go test by lower limb length: adjustment and comparison of scores

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Abstract
We propose a normalization for the Timed Up and Go (TUG) test by incorporating lower limb length (LLL) as an adjustment factor to generate corrected scores, enabling fairer comparisons among individuals of different statures. A total of 353 older adults participated in the study. The results revealed significant differences (p<.001) between the analyzed variables, highlighting the importance of including anthropometric parameters in evaluations. These findings suggest that normalization by LLL can enhance the accuracy of TUG result interpretation, contributing to more adequate assessments in heterogeneous populations.

Introduction
The Timed Up and Go (TUG) test is widely used to assess mobility and fall risk in older populations [1]. However, anthropometric factors, such as height and lower limb length (LLL), can significantly influence performance, complicating comparisons between individuals with different body types. Individuals with greater LLL tend to achieve shorter TUG times due to their longer stride length. Moreover, lower limb length affects optimal walking speed, as individuals with longer legs tend to exhibit more efficient locomotion at higher speeds compared to those with shorter stature [2]. Despite the importance of these factors, there is a lack of studies normalizing the TUG by LLL. Thus, the proposal to adjust TUG performance by incorporating LLL represents an innovative approach with the potential to improve functional assessment. This study, therefore, introduces a TUG normalization formula based on LLL to obtain adjusted scores and compare them with unadjusted scores.

Methods
This cross-sectional study analyzed baseline data from a controlled clinical trial conducted at the "Reference Center for Aging and Movement" in Brazil. Exclusion criteria included being under 60 years of age and having significant gait limitations. The Timed Up and Go test was performed following standard protocols [3]. Participants began the test seated on a chair and, at the evaluator's signal, stood up, walked 3 meters in a straight line, turned at a marked point, returned, and sat back down [3]. The total time to complete the task was recorded [3]. The LLL was measured in meters, from the greater trochanter to the ground. The adjusted TUG score ($TUG_{adjusted}$) was calculated as $100 \cdot TUG \div \sqrt{LLL}$, while the unadjusted TUG score (TUG_{simple}) was calculated as $100 \cdot TUG$. The two scores were compared to evaluate the impact of LLL adjustment using Student's t-test.

Results and Discussion

A total of 353 older adults were evaluated, 78.3% of whom were women, with a mean age of 72.8±6.97 years, height of 159.1±12.4 cm, and LLL of 0.84±0.06 m. TUG performance was 6.55±1.82 seconds, with a TUG_{simple} score of 654.79±182.48 and a $TUG_{adjusted}$ score of 716.87±206.73. The results demonstrated a statistically significant difference between TUG_{simple} and $TUG_{adjusted}$ (p<.001; Table 1).

Table 1: Analysis of the studied variables.

	P value	t	Cohen' d
TUGa *vs* TUGs	<.001	34.765	-1.850

If all individuals in our sample performed the test in a fixed time of 5 seconds, the scores would vary according to LLL. In this scenario, the standardized time would demonstrate that individuals with longer legs exhibited inferior performance compared to those with shorter lower limbs (Figure 1).
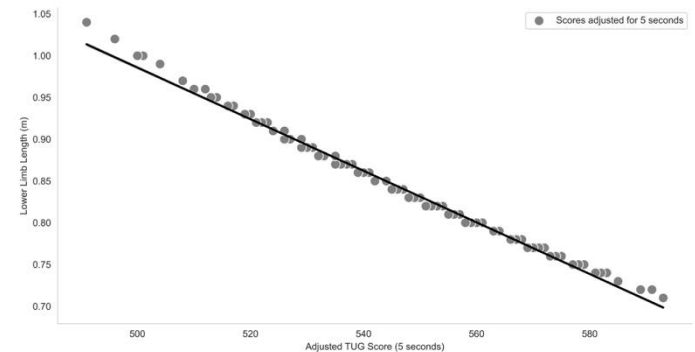

Figure 1: LLL impact on the estimated TUG score.

Conclusion
The proposed adjusted formula proves to be a promising tool for improving the accuracy and interpretation of TUG results in functional assessments by accounting for anthropometric differences among individuals. The findings of this study highlight the relevance of LLL-based adjustment, contributing to fairer comparisons of functional performance in heterogeneous populations.

References

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