A Novel Method for In-vivo Lumbar Spine Neutral Zone Quantification

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Summary

The neutral zone (NZ) has been demonstrated across in-vitro studies as a sensitive measure for passive tissue injury. In-vivo work thus far has struggled to quantify the NZ with the same level of accuracy. To date, in-vivo studies have used a manual passive jig [2]. However, a limitation of this approach is that it cannot capture the full range of motion of a participant's lumbar spine in a single trial, particularly surrounding neutral postures. A motorized passive jig was developed as a novel method to quantify the neutral zone in-vivo. This motorized jig enables participants to undergo their full lumbar range of motion in a single trial, allowing the neutral zone to be calculated using metrics identical to those of in-vitro work. In this investigation, the limits of the neutral zone, stiffness, and the neutral zone relative to static standing and peak flexion during perturbation trials were quantified.

Introduction

The neutral zone (NZ) is commonly referred to as the subset of spinal range of motion in which there is limited resistive activity of the passive tissues and muscles [1,2]. This ideal range of motion for the spinal passive tissues prevents excessive strain that can lead to tissue failure and injury [2]. NZ is used as a sensitive biomechanical measure for the prediction of passive tissue injury [3,4]. While in-vitro studies use NZ stiffness metrics of ±0.05 Nm/° to define NZ limits [4,5], most in-vivo studies have focused on broader stiffness areas (e.g., the low stiffness zone) or utilized a larger cutoff limit than what is typically used in traditional in-vitro work [2]. Therefore, to more accurately calculate the NZ in-vivo, a motorized passive jig was developed to record lumbar spine flexion and extension in one complete, controlled trial [4].

Methods

Seventeen healthy participants completed a static standing trial and three perturbation trials followed by quantification of their NZ via a motorized, frictionless jig. A motion capture system with reflective markers was used to track the kinematics of lumbar spine posture throughout the protocol. The jig included a stationary lower body cradle with a dynamic upper body cradle attached to a controller which maintained a constant speed of 0.5°/sec. A torque transducer mounted in line with the motor was attached to a sliding rail system allowing for movement of the pivot point from the participants' estimated L4-L5 joint. Moment angle curves were developed, NZ length, stiffness, upright standing angle and perturbation responses relative to one's NZ were computed [5].

Results and Discussion

The average NZ range was quantified between 9.37 ° (±9.60°) and 24.37° (±10.56°) of extension with an average stiffness of 0.13Nm/° (Figure 1). 41% of participants stood within their NZ range and 47% remained within their NZ in response to an unexpected perturbation. Participants stood on average, 60.85% away from their NZ extension limit. During perturbations, participants exceeded their NZ flexion limit by 11.82%.

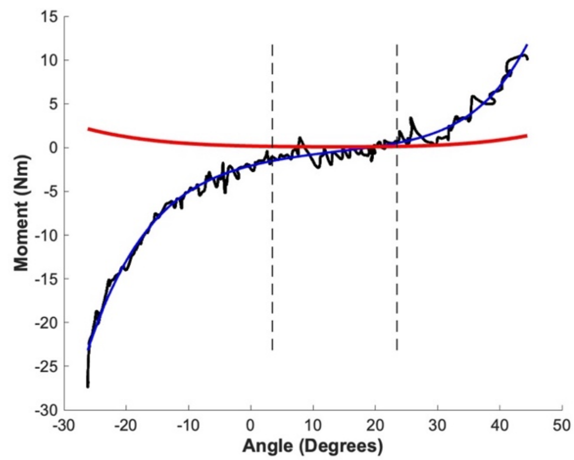

Figure 1: A combined flexion-extension trial in passive jig. Dashed lines indicate the NZ. The red line indicates the 0.05Nm/° stiffness cut-off for the NZ.

The NZ values collected in this study are the first to show comparable metrics to previously reported values in-vitro [4,5]. Given that the current work suggests healthy individuals stand within their computed NZ, these results could be compared with clinical populations (e.g., low back pain, disc degeneration) to provide valuable information on standing position and response to perturbation relative to NZ.

Conclusions

These findings introduce a novel method for collecting NZ in-vivo, with increased accuracy. Given the sensitivity of NZ as an injury predictor, this provides future avenues of research on the impact of NZ and how people respond relative to their individual NZ.

References

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