Quantitative Instrumentation for Cone of Economy Analysis:
Integrating Radiographic Imaging with Clinical Assessment

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Disclosures: Nothing to disclose

Introduction: Postural instability and misalignment are key factors contributing to increased fall risk among the elderly, often resulting in significant physical injuries, diminished quality of life (QOL), and elevated healthcare expenditures. Accurate assessment of postural stability is therefore essential for effective fall prevention strategies. The cone of economy (CoE), a biomechanical concept describing the permissible range of motion of the center of mass and head required to maintain an energy-efficient upright posture, offers valuable insights into balance control. However, current methodologies for quantifying the CoE are limited by complexity, high cost, and the need for extensive post-processing. In this study, we present a novel, real-time measurement system capable of assessing both external and internal components of the CoE (Figure 1). This apparatus provides a practical and cost-effective alternative to traditional approaches, enabling more accessible and scalable evaluation of postural stability in clinical and research settings.

Methods: A controlled experimental study was conducted to develop and validate the proposed CoE measurement apparatus within a laboratory environment, utilizing a cohort of healthy young adults. The apparatus comprised two spherical measurement units designed to independently monitor the motion of the pelvis and the T1 vertebra. Each unit integrated dual-axis rotational magnetic encoders along with a linear displacement sensor, enabling precise three-dimensional capture of postural motion contours. This configuration facilitated accurate quantification of segmental movement critical to CoE analysis (Figure 2).

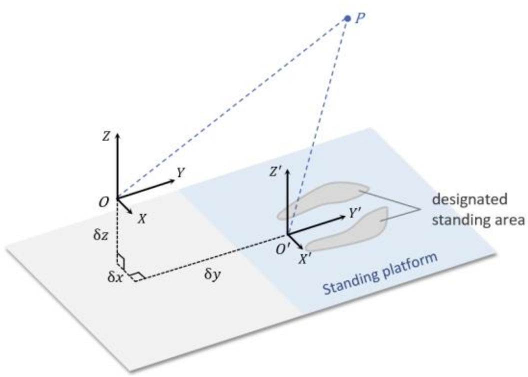
Results: Validation experiments demonstrated the reliability of the proposed measurement system, yielding an average error of less than 1.5 mm. Findings confirmed that the CoE does not conform to an idealized geometric cone, but rather assumes an irregular conical shape influenced by individual physiological characteristics, such as body height and weight. The average range of sway (RoS) for the external CoE measured at the T1 vertebra was 42.7 cm in the coronal plane, 47.6 cm in the sagittal plane, and 12.5 cm in the vertical axis. At the pelvic level, the corresponding values were 14.3 cm (coronal), 13.4(sagittal), and 8.0 cm (vertical). In contrast, the internal CoE exhibited smaller RoS values: at T1, the sway was 10 .4cm (coronal), 6.9 cm (sagittal), and 2.0 cm (vertical), and at the pelvis, 8.2 cm (coronal), 5.8 cm (sagittal), and 2.2 cm (vertical). Notably, the external CoE demonstrated a greater range of sway in the anterior direction, reflecting the compensatory role of the feet in maintaining balance during forward displacement of the center of gravity (Figure 3).

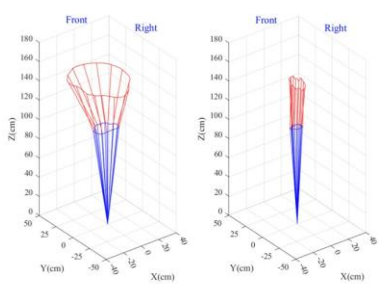
Discussion: Preliminary findings indicate a stronger correlation between external CoE parameters and participant height compared to internal CoE measures, suggesting anthropometric influence on postural control dynamics. These results lay the groundwork for future CoE research with potential applications in fall risk assessment and balance evaluation.

Significance/Clinical Relevance: This study presents a reliable and cost-effective apparatus capable of real-time CoE measurement, providing dynamic, quantitative insights into postural stability. The system holds promise for personalized balance assessment and clinical integration in fall prevention strategies.

REFERENCES:
[1] Masud T, Morris RO. Epidemiology of falls. Age Ageing. 2001;30 Suppl 4:3–7. https://doi.org/10.1093/ageing/30.suppl_4.3.
[2] Hartholt KA, van Beeck EF, Polinder S, van der Velde N, van Lieshout EM, Panneman MJ, et al. Societal consequences of falls in the older population: injuries, healthcare costs, and long-term reduced quality of life. J Trauma. 2011;71:748–53. https://doi.org/10.1097/TA.0b013e3181f6f5e5.
[3] Dhital A, Pey T, Stanford MR. Visual loss and falls: a review. Eye (Lond). 2010;24:1437–46. https://doi.org/10.1038/eye.2010.60.
[4] Keenan MA, Perry J, Jordan C. Factors affecting balance and ambulation following stroke. Clin Orthop Relat Res. 1984;(182):165–71. https://doi.org/10.1097/00003086-198401000-00021.
[5] Chen HY, Yang MH, Lin YP, Lin FH, Chen PQ, Hu MH, et al. Impact of cervical sagittal parameters and spinal cord morphology in cervical spondylotic myelopathy status post spinous process-splitting laminoplasty. Eur Spine J. 2020;29:1052–60. https://doi.org/10.1007/s00586-019-06247-z.

IMAGES AND TABLES:





(a) (b)