OPTIMAL INERTIAL SENSOR PLACEMENT FOR DETERMINING TRUNK INCLINATION

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INTRODUCTION

Working in a flexed trunk posture results in high back loading and is an important risk factor for the development of back pain [1]. Therefore, in ergonomic workplace evaluation, trunk inclination (TI) is used often to quantify back loading. An inertial sensor (IS) can measure inclination with a high accuracy [2] and can be used to measure TI by placing it on the trunk. Because the trunk is not a rigid segment, wrong placement of the IS on the back will result in either an over- or underestimation of the TI. The aim of the present study was to determine the optimal IS placement for the determination of TI.

METHODS

TI was measured during a lifting task in which 10 male subjects moved a crate from the ground to a table (Figure 1). To provoke a large TI, subjects were asked to keep their legs straight. Gold standard TI was defined as the angle between the vertical and the line through the L5/S1 joint and the center of mass (COM) of the trunk (abdomen + thorax + head). The position of the L5/S1 joint and the trunk COM were estimated with a linked segment model (LSM) [3], and followed over time by relating them to Optotrak marker clusters placed on each segment.

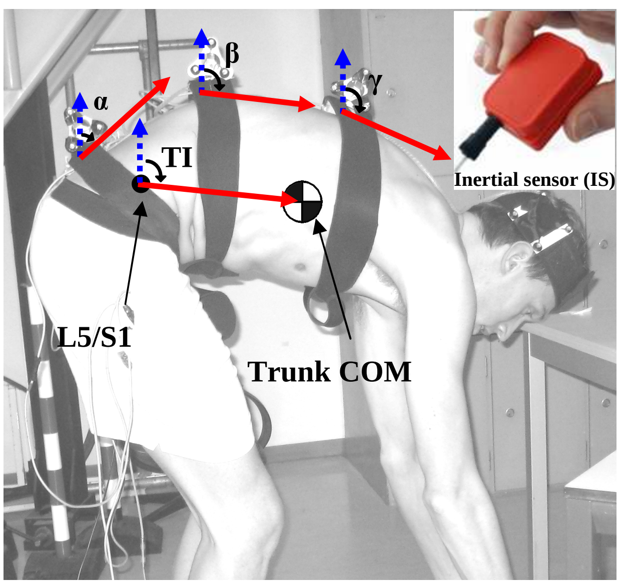

Figure 1: Picture of an experimental trial illustrating the way the trunk inclination was determined with the gold standard LSM (TI), and with an IS (β) replaced in small steps from the thorax (γ) to the pelvis (α).

TI was estimated with an IS located between the thorax and pelvis. Lifting trials were repeated and, in between trials, the IS was shifted in small steps from the thorax to the pelvis. Inclination of the IS was measured with respect to the start of each trial where subjects were standing upright.

RESULTS AND DISCUSSION

Figure 2 shows the RMS error (calculated over the whole lift) between the TI determined with the LSM (gold standard) and the IS, as a function of the location of the IS on the back. Optimal IS placement, determined per subject, resulted in a very small RMS error (generally around 2º). Because optimal sensor placement differed somewhat between subjects, the average curve does not show such clear optimum. For the average curve, the mean + standard deviation RMS error was smallest for IS placement at about 25% of the distance from the midpoint between the posterior superior iliac spines (MPSIS) to the spinal process of the 7^{th} cervical vertebrae (C7). Notably, the RMS error increased much faster when the IS was moved towards the SIPS than when it was moved towards C7.

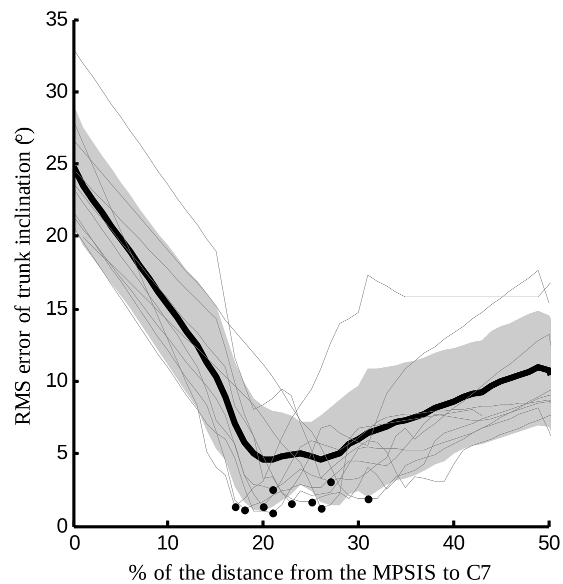

Figure 2: RMS error between the TI determined with the LSM (gold standard) and the IS as function of the location of the IS on the back. Thin lines and black dots depict, individual curves and individual optimal IS placements, respectively. The thick black line and the gray area around it are the average curve and the standard deviation of this average curve.

CONCLUSIONS

When measuring trunk inclination with inertial sensors, optimal sensor placement is at about 25 % of the distance from the MPSIS to C7.

REFERENCES

1. Hoogendoorn WE, et al. Spine. 25(23):3087-3092, 2000
2. Luinge HJ, et al. M*ed. Biol. Eng. Comp.* 43:273-283, 2005
3. Leva P.*J Biomech.* 29(9):1223-1230, 1996
4. Reynolds HM, et al. Technical report, FFA Civil Aeromedical Institute, Oklahoma, 1982