ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

CONTROL STRATEGY IN POSTURAL-MANUAL INTERACTION: IS THE PRIORITY BALANCE OR CONFIGURATION?

[1]Ian Loram
[1]School of Healthcare Science, Manchester Metropolitan University, UK; email: i.loram@mmu.ac.uk

SUMMARY

The principles underlying normal healthy and disordered postural control are currently under debate. It is unknown whether the postural system normally prioritizes restriction of kinematic degrees of freedom at the expense of muscular costs or prioritizes exploitation of degrees of freedom minimizing joint moments. Here static, manual load bearing is used as an internal perturbation to probe the normal strategy of the postural system. In accord with recent evidence [1, 2], response to perturbation reveals a priority to restrict kinematic degrees of freedom within the leg while allowing joint moments that are substantially away from the minimum possible. Results show that with increased awareness through instruction and training, the control priority can be altered with potential for improving balance and reducing injury.

INTRODUCTION

Motor control is thought to be global in that focal manual function involves temporally and hierarchically prior control of the configuration of all bodily segments. Utilization of the available kinematic degrees of freedom usually increases with development and skill acquisition and declines with ageing, disease and perceptual-psycho-physiological state such as body armoring in fear or anxiety. The current control strategy can be diagnostic of condition and prognostic of progression regarding motor performance and potential for injury. Our underlying aim is to develop diagnosis of control strategy in individuals.

For humans, the characteristic bipedal posture requires that the shank, thigh, torso and head segments are aligned one on top of the other. The body is unstable, so postural control requires balance, which is taken here to mean the maintenance of equilibrium and reduction of unnecessary joint moments. Because standing requires that both balance and configuration are controlled it is difficult to decide which goal has priority in the current, motor set: is it maintenance of configuration (posture) or the reduction of unnecessary joint moments (balance)? Postural control concerns stabilization rather than elimination of sway [3]. However, recent evidence using gentle sagittal perturbations at the knee joint during normal standing revealed generalized, restriction of kinematic degrees of freedom at the ankle, knee and hips joints [1].

Here we use a manual task as an internal perturbation to place the goals of posture and balance in conflict, and ask which goal has the priority.

METHODS

Twelve healthy participants stood quietly and symmetrically on a force-plate (AMTI, OR6) while holding a 5 kg bar in both hands. Participants were instructed to stand with arms hanging down, then to slowly raise the bar vertically to shoulder level, then slowly move the bar horizontally forwards to the maximum extent, then to hold the bar in that forward position. To minimize acceleration forces and ensure that conditions appropriate to static analysis applied throughout, each stage was timed to proceed smoothly through 10s. Segmental motion was recorded using a 10 camera motion capture system (VICON) full body marker set aligned to the force plates within 5mm accuracy. Following repeated unrecorded familiarization, when participants were confident, the procedure was recorded three times (Trials 1-3) with rests between trials. After a break, participants were instructed in the principle of allowing joints to rotate to allow the combined center of mass to remain undisturbed. Participants were asked to pay attention to the pressure under their feet. After familiarization, the procedure was recorded once (Trial 4) during which participants were given verbal feedback when the sagittal point of application of the ground reaction force moved from the initial position. All participants provided written informed consent and all procedures were approved by the local ethics committee.

Prediction: In the absence of external forces, if joint resistance were low, configuration unconstrained and active joint moments minimized, then during forward movement of the bar, the body should move posteriorly leaving the combined center of mass of the body and bar in its initial position which was usually slightly anterior to the ankle joint. If the primary goal was to maintain postural leg-trunk configuration, postural control would ensure the leg and trunk positions would remain constant and the combined center of mass would move forwards.

Reducing left and right to a planar sagittal description, the change in angles and moments of ankle, knee and hip joints, and the center of gravity (CoG) (sagittal point of application of the ground reaction force low pass filtered at 0.5 Hz) are presented. Mean values are compared between the period during which the bar was held in the fully extended position (30-40 s) and the initial period (0-10 s) (Figure 1). Quantities are reported as mean±s.d. and tested using ANOVA with Trial and Participants as fixed factors.

RESULTS AND DISCUSSION

Summarizing mean behavior of 12 participants, during Trials 1-3 (n=36), in response to sustaining the 5kg bar anteriorly at full arm extension, the center of gravity moved anteriorly, 26±17 mm (Fig 1A) and the absolute joint moment summed over the ankle, knee and hip increased 32±39 Nm (Fig 1B). Trial 4 showed significant reductions in center of gravity movement ($F_{(3,47)}=22$, $p<10^{-7}$) and

summed joint moment ($F_{(3,47)}$=20, $p<10^{-6}$) compared with Trials 1-3, with no significant differences between Trials 1-3 (Tukey *post hoc*, at alpha 0.05) in either quantity. During Trial 4, in response to sustaining the 5kg bar anteriorly there was little change in CoG 1±14 mm (Fig 1A), a reduction in summed joint moment 4±44 Nm (Fig 1B) associated with altered knee flexion (Fig 1C) and minimal changes in joint moment including a reduction in hip moment.

This internal perturbation of normal standing revealed, in Trials 1-3, a priority to maintain leg configuration at the expense of increasing joint moments. There was little change with repetition, the trials followed ample familiarization and participants were not led to use any particular strategy. These facts suggest the priority given to control of configuration was normal for these participants. In Trial 4, the dramatic reduction in joint moments following detailed instruction in strategy, attention to appropriate sensory information and prompt, accurate feedback shows the extent of the potential for prioritizing minimization of joint moments (balance) over configuration.

CONCLUSIONS

Within normal postural control and during postural-manual interaction there is well established priority to fix configuration of the legs and trunk at the expense of cost in overall muscular effort. This result is in agreement with recent evidence applying gentle perturbations to the knee joint during normal posture [1, 2]. We note two areas of relevance. First, some professions, including musicians, sustain loads manually for extended periods and are prone to profession related injury. Second, an underlying strategy of kinematic rigidity increases risk of falling. Through appropriate education, improvement in balance and postural-manual interaction is eminently achievable.

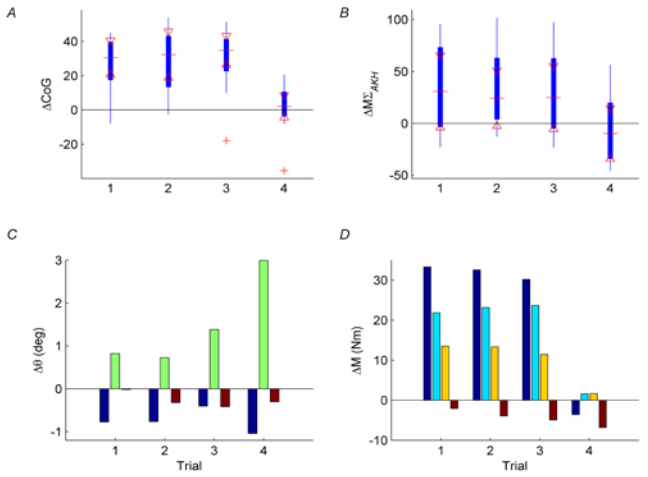

Figure 1: **Effect of sustaining 5kg bar anteriorly at full arm extension on configuration and joint moments**. Change between period of maximum perturbation (30-40s) and initial rest (0-10s) in ***A*** sagittal CoG position; ***B*** absolute joint moment summed over ankle, knee and hip; ***C*** joint angle for ankle, knee hip respectively; ***D*** absolute joint moments for combined, ankle, knee and hip respectively. Panels A and B show median, interquartile range, range and outliers in red bar, blue bar edge, whiskers and red crosses. Panels C and D show mean values only, excluding variation between participants for clarity.

ACKNOWLEDGEMENTS

Thanks are offered to Irene Di Giulio, Linda Tersteeg and Brian Bate for their support during preliminary work and data collection, and to the participants who willingly gave their time.

REFERENCES

[1] Di Giulio, I., Maganaris, C., Baltzopoulos, V., and Loram, I., 2011, "Perturbations reveal knee role in the control of the whole body in standing," *XXIIIrd Congress of the International Society of Biomechanics*, ISB, Brusselsl, Belgium, p. 132.

[2] Di Giulio, I., 2011, "Biomechanical and control mechanisms for sustaining the human postural attitude", PhD Thesis, Manchester Metropolitan University Manchester.

[3] Kiemel, T., Zhang, Y., and Jeka, J. J., 2011, "Identification of Neural Feedback for Upright Stance in Humans: Stabilization Rather Than Sway Minimization," *Journal of Neuroscience*, 31(42), pp. 15144-15153.