ACCURATE PRODUCTION OF PATTERNS OF THE TOTAL MOMENT BY A SET OF FINGERS

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INTRODUCTION

During isometric force production by an effector, force variability typically increases with the level of force [1]. When several fingers of the hand press down in parallel to produce a required time profile of the total force, there is little variation in the total force variability over a wide range of the total force [2]. This results from force-stabilizing multi-finger synergies. Tasks of accurate total force production are also accompanied by synergies stabilizing the total moment in pronation/supination, even when the subjects are instructed and get visual feedback on the total force but not on the total moment [2]. These findings have been interpreted as consequences of everyday practice with tasks that typically impose more strict accuracy constraints on total moment production. We investigated the relations between the total moment and its variability during the multi-finger production of accurate time profiles of the total moment. We expected the hypothetical multi-finger synergies to lead to complex relations between the moment magnitude and its variability.

METHODS

Twelve healthy, right-handed volunteers, six males and six females participated in the experiment. The subjects sat comfortably in a chair and positioned the right forearm on the horizontal board directly in front of the subject. The fingertips of the right hand were placed on unidirectional force sensors spaced to fit the subject's individual anatomy. Changes in the forearm and hand position were prevented by a set of Velcro straps and using a custom-fitted wooden piece placed under the palm. The subjects watched a 17" monitor that showed a target moment time profile and the actual total moment in pronation/supination produced by the normal finger forces with respect to the midpoint between the middle and ring fingers (effort into pronation was considered positive).

After a few practice trials, the subjects were required to follow, as closely as possible, a pattern shown on the screen with the cursor. There were two tasks, the Ramp-Task and the Sine-Task illustrated in Figure 1. Each task required accurate production of a moment profile starting from a certain level into pronation (normalized by subject's index finger maximal force), on average about 20 Ncm, to the same level into supination and then back to the original pronation moment. The total time of a trial was 12 s; the time intervals of moment changes were 3 s each. Twenty-five trials were performed at each task. Average force and moment time profiles and their variance profiles were computed over each set of 12 trials.

RESULTS

Both ramp and sine changes in the total moment showed two phases, a decrease in the forces by fingers that produced the moment in one direction followed by an increase in the forces of fingers that produced the moment in the opposite direction.

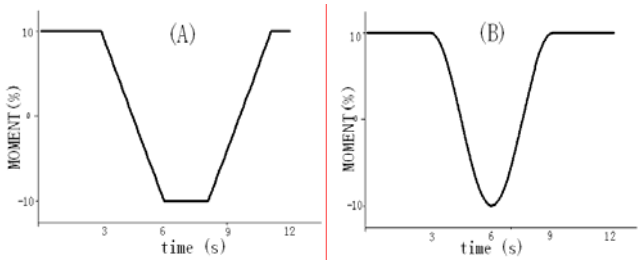

Figure 1: The Ramp-Task (A) and the Sine-Task (B). Moment axes are in percent of the product of index finger MVC by its lever arm.

In both tasks, the total normal force produced by the fingers increased over the trial duration such that it was significantly higher at the end of the task (on average, a two-fold increase from 8 to over 16 N) while the subjects produced the same moment as at the trial initiation. No clear relations were observed between total force and its variability and between total moment and its variability. However, moment variance was significantly higher, on average by 70%, when the total moment was close to zero than at its peak values; this was more pronounced during moment changes from pronation to supination. High moments into supination were accompanied by higher variance, on average by 66%, than high moments into pronation.

DISCUSSION AND CONCLUSIONS

Our observations suggest the existence of complex relations between magnitude of a moment produced by a set of fingers in isometric conditions and moment variability. Apparently there is no simple rule that would predict moment variability based solely on its level. Moment variability depends on the rate of moment change, on the time history of getting to a particular moment value, and it shows differences between the pronation and supination moments. Moment changes from a steady-state to another level and back to the same steady-state are accompanied by an increase in the finger force level, which is not dictated by the task and looks counter-intuitive: It involves unnecessary force production by fingers opposing the required moment. Further studies of multi-finger moment production are needed to resolve these mysteries.

REFERENCES

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