

Possibility of intrinsic muscle contractile properties as an index of maximal muscle strength and muscle fatigue

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Introduction

Measurement of contractile properties as a result of the electrical stimulation is a useful method for determining muscle output and muscle contractile fatigue. As intrinsic muscle contractile properties, post-activation potentiation (PAP) and summation of contraction are well known. However, systematic studies of PAP ability and force summation ability to detect the maximal force-generation capacity and muscle fatigue have not been conducted.

Objectives

This study aimed to investigate whether the intrinsic muscle contractile properties, which include force summation and PAP, can be used as indices of maximal muscle strength and muscle contractile fatigue.

Methods

Seven right-handed males aged 29–32 years [height (mean \pm SE): 177 \pm 3.2 cm, weight: 74 \pm 3.5 kg] volunteered for this study.

While lying in the supine position, subjects performed fatigue exercise dynamic dorsiflexion of the right ankle for 2 min against a resistance load attached to the toes on the right foot. The magnitude of the resistance load was calibrated to 30% of MVC for each subject.

The subjects were asked to synchronize the rhythm of dorsiflexion with a 1-Hz metronome beat. The 2-min exercise periods were repeated 3 times (E1, E2, and E3) each separated by a 5-min rest period (i.e., an intermittent exercise test).

The isometric evoked torques and MVC torque were measured before E1, immediately after each exercise period, and once during a recovery period (15 min after the end of the third exercise period). The isometric MVC torque measurements were taken for 5 s with the ankle at 90° using a multifunctional dynamometer. Before and after MVC, the isometric torques evoked by single stimulus (Pt), 2-pulse trains (PT2), and 3-pulse trains (PT3) in the tibialis anterior (TA) muscle were measured.

Intrinsic muscle contractile properties were defined as evoked peak torque (single stimulus, two-pulse trains, and three-pulse trains), PAP, and ability of torque summation.

The ability of torque summation was estimated by torque contribution of second stimuli of two-pulse trains (C2) and third contribution of three pulse trains (C3). The contribution of the response to the Nth stimulation was determined by subtracting the response to the N-1 stimulation from that to the N stimulation. Non-PAP-evoked torques, PAP-evoked torques, and MVC torques of dorsiflexion at isometric contractions were measured at an ankle angle of 90° in each rest period. The electrical stimulation was delivered from the common peroneal nerve near the fibular head. The responses to two-pulse trains and to three-pulse trains, which were delivered with a constant inter-pulse interval of 10 ms (100 Hz), were recorded.

Results & Discussion

The mean absolute values of MVC torque of all subjects decreased gradually with the progression of fatigue; some recovery was observed after 15 min of recovery time (Fig. 1A). Regardless of with or without PAP, the peak torque evoked by a single stimulus, two-pulse trains, and three-pulse trains decreased with the increase in fatigue (Fig. 1B). Although C2 and C3 without PAP decreased with the increase in fatigue, the pattern of changes in C2 and C3 with PAP differed from that in other parameters (Fig. 1C).

The percent fall was greater in the evoked torque parameters than in the MVC torque (Fig. 2A and 2B). These results suggest that the measurement of intrinsic muscle contractile properties overestimates the muscle fatigue during MVC of dorsiflexion at isometric contraction.

Moreover, the present study found that, with or without fatigue, the absolute values of almost all evoked torque parameters were significantly positively correlation with absolute MVC torque in inter-subject data (Fig. 3A and 3B).

In addition, the magnitude of PAP at Pt in almost all fatigue levels was significantly positively correlated with absolute MVC torque in inter-subjects data (Fig. 3C). Thus, the measurement of intrinsic muscle contractile properties can be used as an index of maximal muscle strength with or without fatigue.

Conclusions

The intrinsic muscle contractile properties with or without PAP in the TA overestimate fatigue during the MVC. However, force summation parameters and PAP can be used as index of maximal muscle strength with or without fatigue.

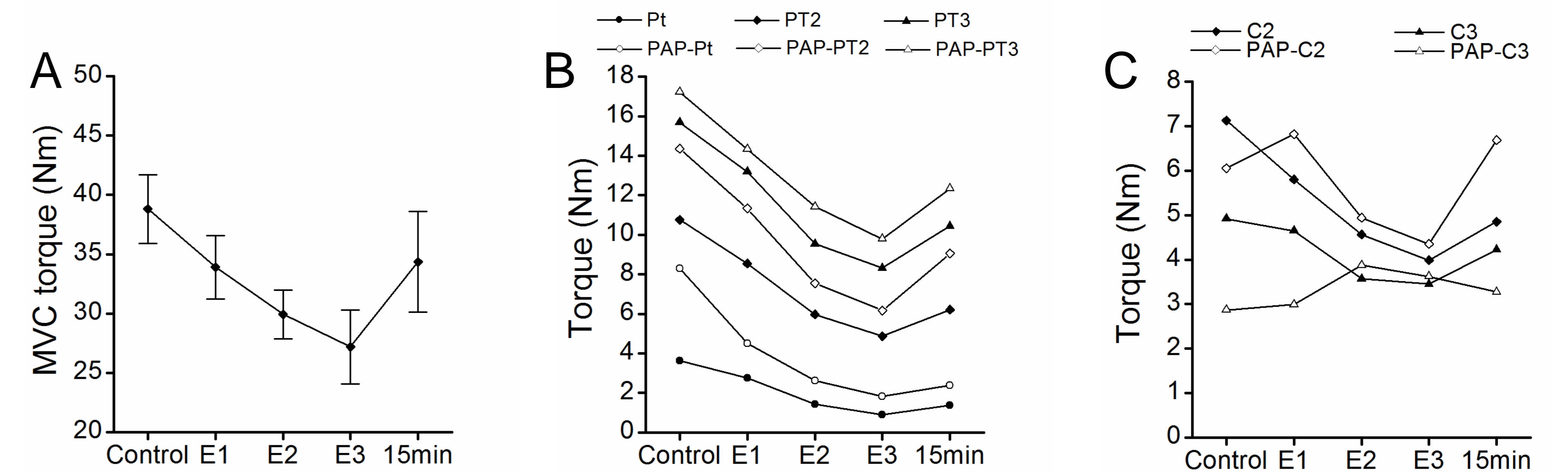


Figure 1. The mean absolute values of MVC torque (A), mean evoked torques (Pt, PAP-Pt, PT2, PAP-PT2, PT3, and PAP-PT3) (B), and mean torques as a result of the second and third stimulations (C2, PAP-C2, C3, and PAP-C3) (C).

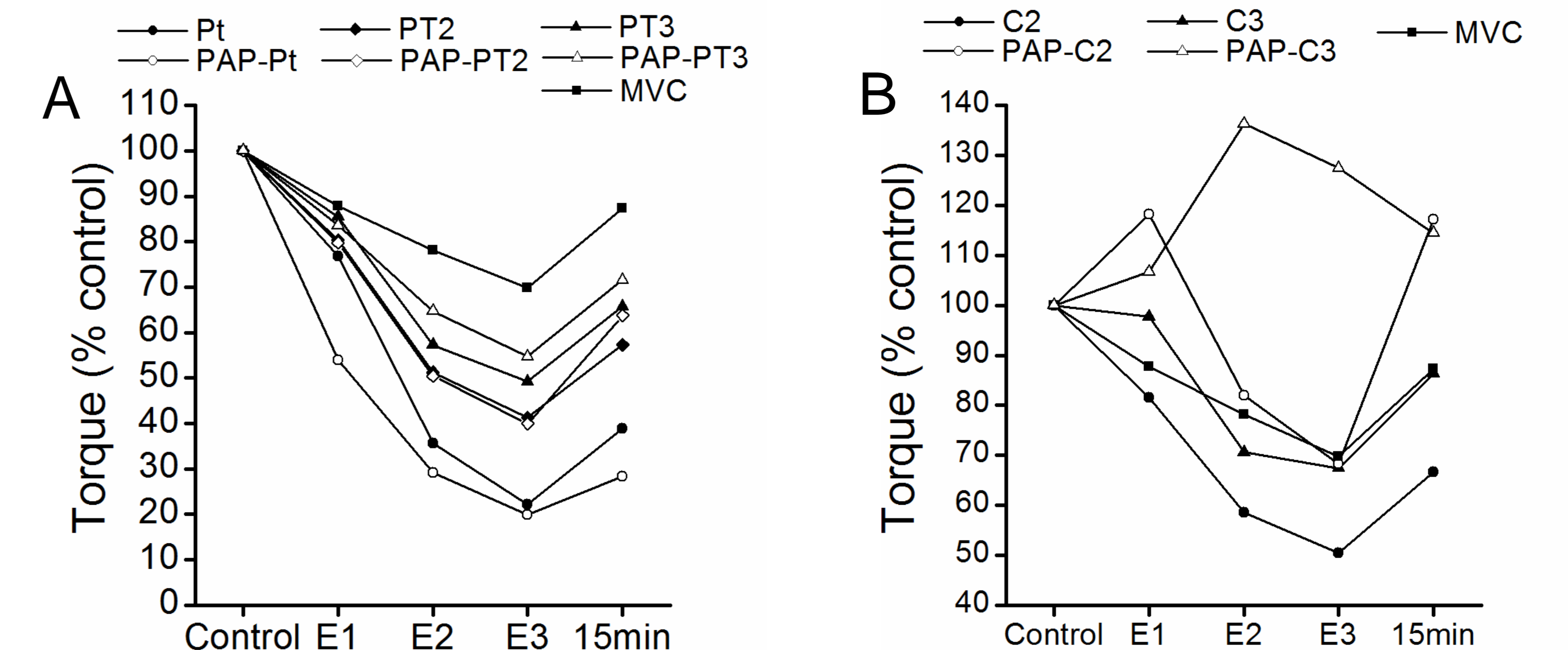


Figure 2. MVC and evoked torques relative to the control values (A). Torque contributions of second and third stimulations relative to the control values (B).

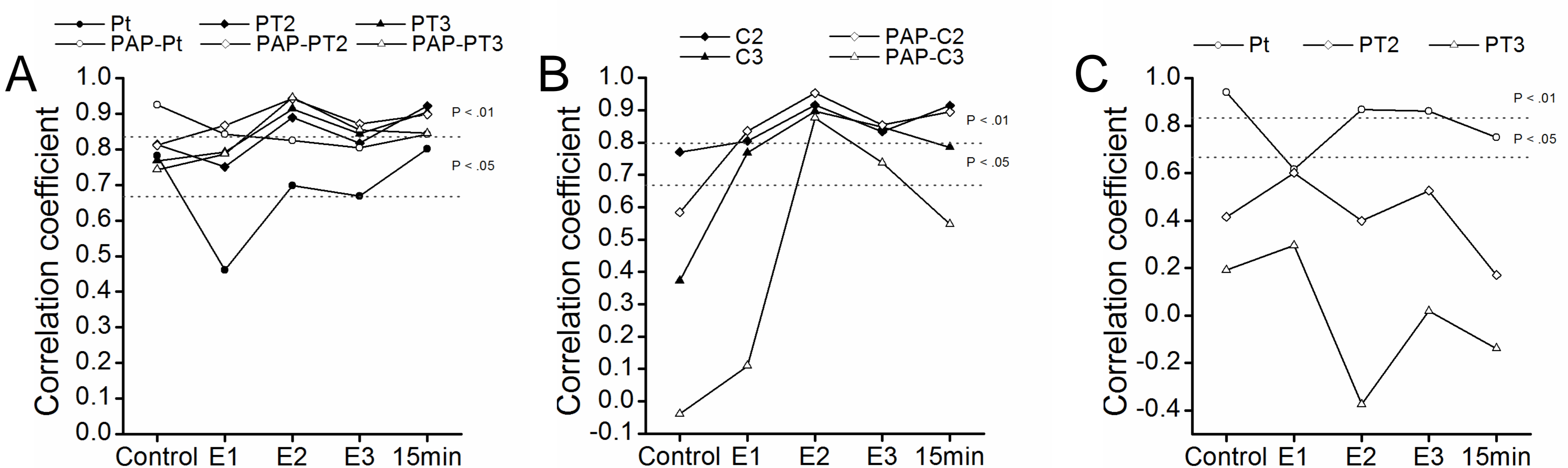


Figure 3. Correlations between absolute MVC torque and absolute evoked torques (A). Correlations between absolute MVC torque and the absolute torque contributions of the second and third stimulations (B). Correlations between absolute MVC torque and absolute PAP values at Pt, PT2, and PT3 (C)

