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THE HUMAN CAPACITY TO PRODUCE EXPLOSIVE TORQUE IS INFLUENCED BY CONTRACTION TYPE AND ACCELERATION

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INTRODUCTION

The effects of the type of skeletal muscle contraction (concentric, eccentric or isometric) on maximal voluntary torque (MVT) production in humans are well documented [1,2], but little is known about the influence of contraction type on the ability to increase torque rapidly from a low or resting state (explosive torque production). We recently published novel evidence showing that the ability to utilize the available MVT during explosive efforts was considerably greater (>60%) in concentric than any other type of contraction [3]. This appeared to be due to greater agonist activation during the concentric contractions, as measured by normalizing voluntary explosive torque to the maximum capacity for explosive torque production elicited during an electrically evoked supramaximal octet (300 Hz) contraction. However, our previous study only investigated explosive torque and agonist activation at one acceleration (2000°.s^{-2}), in both concentric and eccentric contractions [3], and thus the results were only relevant to the contractile velocities achieved at this acceleration. Agonist activation at MVT is known to increase with increased concentric contractile velocity [1,2]. If a similar effect occurred in explosive concentric efforts, we may expect a greater utilization of the available MVT in explosive concentric contractions performed at fast compared to slow velocities. This theory could be tested by comparing torque production in explosive concentric contractions performed at different constant accelerations that elicit distinct peak velocities. The purpose of this study is to assess the effects of both contraction type and concentric contractile acceleration on the ability to utilize the available MVT in explosive efforts.

METHODS

Thirteen healthy male volunteers visited the laboratory on 4 separate occasions; two familiarization sessions, and two measurement sessions. During the measurement sessions participants completed a series of explosive voluntary knee extensions on an isovelocity dynamometer in four conditions: eccentric (ECC), isometric at a knee angle of 123° (ISO), concentric slow (CON$_{SLOW}$), and concentric fast (CON$_{FAST}$). During the concentric and eccentric conditions the crank-arm slowly moved (at ~10°.s^{-1}) through the range of motion (89°-156°; where 180° = full knee extension) to the start position for either concentric (89°) or eccentric (156°) efforts. Upon reaching the start position the crank-arm accelerated at a constant rate for 52° (concentric efforts, 89°-141°; and eccentric efforts, 156-104°) before decelerating to stop at the opposite end of the range of motion. In ECC and CON$_{FAST}$ the crank-arm accelerated at 2000°.s^{-2} for 225 ms and peaked at 450°.s^{-1}, before decelerating (Table 1). In CON$_{SLOW}$ the crank-arm accelerated at 500°.s^{-2} for 450 ms and peaked at 225°.s^{-1}, before decelerating (Table 1).

Table 1: Crank-arm kinematics during the acceleration phase of eccentric and concentric conditions.

	Acceleration (°.s^{-2})	Angle at start (°)	Angle at end (°)	Peak velocity (°.s^{-1})
ECC	2000	156	104	-450
CON$_{SLOW}$	2000	89	141	225
CON$_{FAST}$	500	89	141	450

In the concentric and eccentric conditions participants were instructed to push as 'fast and hard' as possible at the start of the acceleration phase without pretension or countermovement. The same instruction was given during the ISO condition, only participants started pushing on an auditory signal provided by the same investigator. Active torque measured during the concentric and eccentric conditions was corrected for acceleration and weight of the limb by subtracting torque recorded in the same condition whilst participants were voluntarily passive. In each condition corrected torque was recorded at 50-ms intervals, up to 150 ms, from active torque onset and normalized to MVT recorded at the same crank-arm angle and angular velocity (see below). Torque at 50 ms was also expressed as a percentage of electrically evoked torque at 50 ms in the same condition (see below), to asses neural activation in the early phase of the contraction.

Following the explosive voluntary contractions, participants completed a series of isometric and dynamic maximal voluntary contractions (MVCs). The isometric MVCs were completed at five knee angles (91, 107, 123, 138, and 153°); whilst the dynamic MVCs consisted of 3 reps of reciprocal eccentric-concentric contractions at four isovelocities (50, 100, 250, and 400°.s^{-1}). In all MVCs participants were instructed to push as 'hard as possible'. Data measured during the MVCs was corrected for weight of the limb and entered into a 9-parameter mathematical model that defined MVT as a function of crank-arm angle and angular velocity [1,3]. Interpolated MVT was used to normalize explosive torque recorded during the explosive voluntary contractions.

The femoral nerve of each participant was electrically stimulated to evoke supramaximal octet (300 Hz) contractions in the same four conditions as the explosive voluntary contractions. In the concentric and eccentric conditions octets were elicited ~4-5° into the acceleration phase as pilot testing had shown this to be the point that participants typically started pushing during the voluntary efforts. Participants remained voluntarily passive during all evoked contractions, and torque was corrected for acceleration and weight of the limb before recording evoked torque at 50 ms from torque onset.

Paired t-tests were used to compare conditions at each time point, and significance was accepted at $P<0.05$.

RESULTS AND DISCUSSION

The proportion of MVT achieved at each time point from torque onset during the CON_{FAST} condition was >44% greater than in CON_{SLOW} ($P<0.01$); >64% greater than in ISO ($P<0.001$); and >75% greater than in ECC ($P<0.001$; Figure 1). The proportion of MVT achieved at each time point in CON_{SLOW} was similar to ISO, but >17% greater than ECC ($P<0.05$; Figure 1), whilst normalized explosive torque in ISO was only greater than ECC at 50 and 100 ms ($P<0.05$; Figure 1).

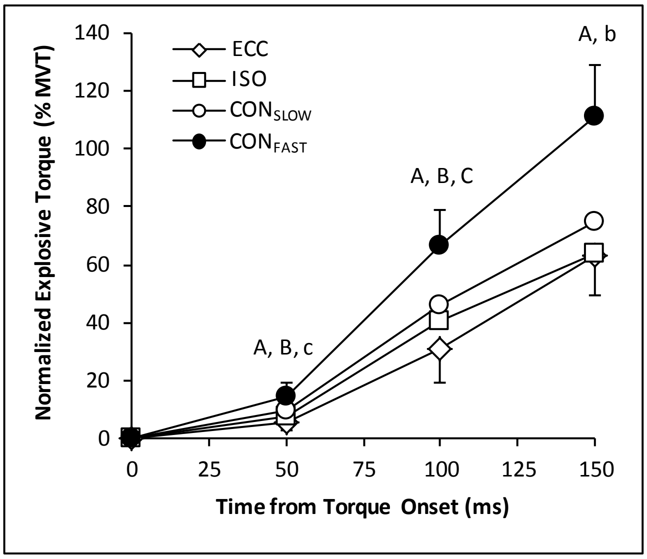

Figure 1: Explosive voluntary torque normalized to MVT at the same crank-arm angle and angular velocity during each condition. Paired differences are denoted by capital ($P<0.01$) or lower case ($P<0.05$) letters; A (CON_{FAST} > all other conditions), B (CON_{SLOW} > ECC), and C (ISO > ECC).

These results concur with those of our earlier study [3], and show that the ability to utilize the available MVT in explosive concentric contractions is considerably greater than in explosive eccentric or isometric contractions. Moreover, these results provide novel evidence that the capacity for explosive torque production is also influenced by concentric contractile acceleration, with greater proportions of MVT being achieved in CON_{FAST} than CON_{SLOW}. Whilst the normalized torque-time curves of CON_{SLOW}, ISO, and ECC showed some similarities, there was a tendency for explosive performance to be greater in CON_{SLOW}, followed by ISO and ECC.

The greater capacity for explosive torque production in CON_{FAST}, followed by CON_{SLOW}, ISO, and ECC, is likely to be due to differences in neural activation between these conditions. This is supported by the results in Figure 2, which show that the ability to voluntarily utilize the muscles' maximum capacity for explosive torque production was greatest in CON_{FAST}, followed by CON_{SLOW}, ISO and ECC. This effect may be the result of a protective neural mechanism, which inhibits activation of the muscle in conditions likely to elicit high loads and high rates of loading, such as eccentric, isometric, and slow concentric explosive contractions.

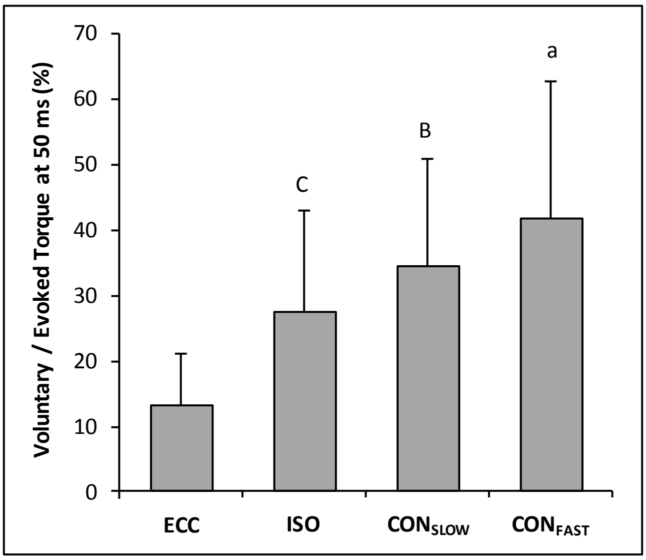

Figure 2: Explosive voluntary torque at 50 ms relative to evoked octet torque at the same time point during each condition. Paired differences are denoted by capital ($P<0.01$) or lower case ($P<0.05$) letters; A (CON_{FAST} > all other conditions) and B (CON_{SLOW} > ECC), and C (ISO > ECC).

In CON_{FAST} MVT was achieved and, in some participants, exceeded within 150 ms (Figure 1). This is consistent with the results of our earlier study [3], and suggests that greater peak torques are achieved at high concentric velocities when the emphasis is on producing explosive, rather than sustained maximal, torque.

CONCLUSIONS

The proportion of available MVT achieved during explosive concentric contractions performed at fast accelerations was considerably greater than in explosive eccentric, isometric, or concentric contractions performed at slow accelerations. This appeared to be due to a more effective neural strategy in the fast, explosive concentric contractions.

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