STRENGTH TRAINING ALTERS THE STRUCTURE OF FORCE FLUCTUATIONS DURING ISOMETRIC QUADRICEPS FEMORIS CONTRACTIONS IN OLDER ADULTS.

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INTRODUCTION

When the resultant joint moment acting at a joint during an isometric contraction is measured it is not constant but rather it fluctuates (e.g., Lippold et al., 1957). These fluctuations limit the ability of an individual to maintain a desired force or to realize an intended limb trajectory (Harris and Wolpert, 1998). These fluctuations are increased in older adults (Tracy et al., 2004).

The size of the force or moment fluctuations has been quantified using the coefficient of variation (CV) of the force (e.g., Tracy et al., 2004). The time dependent structure of the fluctuations has been analysed using Approximate Entropy (ApEn) (e.g., Challis, 2006), which is a dimensionless measure varying between 0 (indicating a signal with high regularity such as a sine wave) and 2 (a signal with low regularity such as white noise) (Pincus, 1991). The Detrended Fluctuation Analysis (DFA) (Peng et al., 1994) has also been used to determine the fractal scaling index (a) of the force signal (e.g., Vaillancourt and Newell, 2003).

A previous study (Tracy et al., 2004) determined that there was no change in the magnitude of the fluctuations quantified using CV during isometric contractions following strength training in older adults. However, force signals produced during isometric contractions have been shown to have fractal scaling index above 0.5 (Vaillancourt and Newell, 2003), indicating a non-normal distribution. The purpose of this study was to use a non-parametric equivalent of CV to confirm the lack of change in the magnitude of the fluctuations with strength training, and to analyse the time dependent structure of the force signal before and after training using ApEn.

METHODS

Eight female subjects aged between 65 and 74 years were recruited following screening to ensure absence of obesity, cardio-vascular, lung, neurological and musculo-skeletal disorders including osteoporosis. Subjects were familiarised with the procedures and provided written informed consent. The Institutional Review Board at The Pennsylvania State University approved all procedures. At the initial testing session, following a five minute cycle ergometer warm-up and practice contractions, subjects performed isometric knee extension contractions using the right leg at a 90 degree knee angle in a Biodex III dynamometer. Subjects performed three maximal voluntary isometric contractions with five minutes rest between each contraction. Subjects then performed contractions at each of the following levels: 75%, 50% and 25% of maximum, using visual feedback. The Biodex moment signal was sampled at 1600 Hz and low pass filtered at 20 Hz using LabVIEW 7.

Subjects underwent a supervised ten week whole body strength training programme including: uni-lateral leg extension performed on both legs, bi-lateral leg press, uni-lateral leg curl performed on both legs and bi-lateral calf raises. After the training period the subjects were re-tested.

A 2.2 second window was selected from the joint moment records at each force level for analysis using a minimum variance criterion. The response variables (CV, fractal scaling index, and ApEn) were calculated for this window. A surrogate analysis of the data determined that the ApEn and DFA results were due to signal properties and not measurement system noise. Statistical comparisons were performed using a three way analysis of variance.

RESULTS AND DISCUSSION

There was no significant change in CV with strength training. The DFA results gave values ranging from 0.9 to 1.7, and a significant increase in the fractal scaling index was seen with increasing force level for each subject ($F=34.88$; d.f.=1,7; $p<0.001$). Values in this range reflect non-normal distributions, therefore a non-parametric equivalent to CV was used to confirm that there was little evidence of change in the magnitude of the fluctuations ($F=2.60$; d.f.=1,7; $p=0.151$).

ApEn did change significantly with force level ($F=32.11$; d.f.=3, 21; $p<0.001$), and following strength training ($F=6.89$; d.f.=1,7; $p=0.034$). Post-hoc comparisons showed that the significant change with strenth training seemed to be related to changes at the 50% and 75% force levels, though these just failed to be significant at a familywise alpha level of 0.05.

That the magnitude of the fluctuations does not change following strength training agrees with previous results for the quadriceps (Tracy et al., 2004). However, the present results show that the ApEn value does change significantly such that it tends to increase with strength training, particularly at intermediate force levels.

CONCLUSIONS

Use of a non-parametric equivalent to the coefficient of variation suggests that there is no change in the magnitude of force fluctuations with strength training of the quadriceps in older adults. However, strength training results in an increase in ApEn particularly at 50-75% of maximum isometric force. ApEn appears to decrease with age (Challis, 2006), possibly as a result of changes in motor unit characteristics such as innervation ratio. The present results indicate that the effects of ageing on force regularity are reversed by strength training.

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