HOW DO AGE-RELATED CHANGES IN NEUROMUSCULAR AND TENDINOUS PROPERTIES INFLUENCE BALANCE RECOVERY USING THE ANKLE STRATEGY?

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INTRODUCTION

Aging is associated with changes in neuromuscular and tendinous properties [1] and a reduced ability to recover balance from an imbalance episode [2]. However, little is known about the relations amongst these factors. The purpose of this study was to determine the relative influence of age-related changes in neural, muscular and tendinous properties on the ability to recovery balance from a forward leaning position using the ankle strategy [3].

METHODS

A computer simulation was developed which consisted of an inverted pendulum with one rotational degree of freedom controlled by two muscles representing the ankle joint plantar flexor (PF) and dorsi flexor (DF) muscle groups. The muscle model was based on a generic 3-component Hill-type model that included force-length and force-velocity behaviours of the contractile component as well as force-length behaviour of the series elastic elements. The contribution of passive elasticity to the ankle joint moment was incorporated as a function of ankle joint angle [4]. Model parameter values were adjusted so that the isometric torque-angle relation was in agreement with experimental ankle joint torque-angle curves [5, 6]. Muscle excitation was adjusted to match an experimentally determined maximum recoverable lean angle (MRLA) of 7.2 degrees (baseline condition) [7].

The effect of 20% alterations to 8 parameters on MRLA was assessed. The parameters were: maximum isometric force (F_{max}), optimum muscle fibre length (L_{opt}), maximum shortening velocity (V_{max}), tendon stiffness (ε_{fmax}), reaction time delay (RTD), activation time constant (τ_{act}) and the maximum excitation of the PF (u_{maxpf}) and DF (u_{maxdf}). Baseline values for each parameter are given in table 1. The model was implemented in forward dynamics mode using Matlab, Simulink and SimMechanics (The MathsWorks, Natick, NA) and solved using fixed step size numeric integration (Step size = 0.001 s, simulation time = 1.5 s).

Table 1. Baseline values for parameters used in the model. See text for definition of terms.

Parameter	PF	DF
F_{max} (N)	7200	1800
L_{opt} (mm)	55	98
V_{max} (Lopt/s)	10	10
L_{slack} (mm)	400	223
ε_{fmax} (%)	5	5
RTD (ms)	100	100
τ_{act} (ms)	55	55
u_{max}	0.328	0.1

RESULTS AND DISCUSSION

The parameters that had the greatest influence on MRLA were F_{max}, u_{maxpf} and RTD, which respectively resulted in 19.0, 17.8 and 4.6% reductions in MRLA. Individual changes to other parameters influenced MRLA by less than 1.9%. When parameter values were adjusted in accordance with age-related changes reported in the literature, MRLA was reduced to 5.3 degrees, a value in relative agreement with experimental values reported in the literature (4.6 ± 1.8 degrees). See [8] for a more detailed description of results.

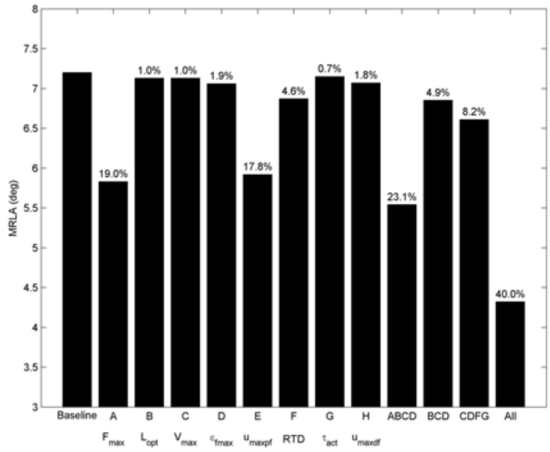

Figure 1. Effect of altering model parameters by 20% on maximum recoverable lean angle (MRLA) using the ankle strategy. F_{max}, L_{opt}, V_{max} and u_{maxpf} were decreased by 20% and ε_{fmax}, RTD, τ_{act} and u_{maxdf} were increased by 20%. Percentage values represent the decline in MRLA relative to the baseline condition (θ_0 = 7.2°). The last 4 columns represent combined effects. See text for definition of terms.

CONCLUSIONS

Overall results suggest that MRLA is most sensitive to PF muscle size and the ability to maximally activate the PFs, and that the combined effect of multiple changes in neural, muscular and tendinous parameters reported to occur with ageing can have a profound effect on the ability to recover balance from a forward fall using the ankle strategy.

REFERENCES

1. Narici, M. et al. *Exerc Sport Sci Rev*, **35**, 126–34, 2007.
2. Grabiner, M. et al. *J Electromyogr Kinesiol*, **18**, 197–204, 2008.
3. Horak, F. *Age Ageing*, **35**, ii7–ii11, 2006.
4. Reiner, R. et al. *J Biomech*, **32**, 539-44, 1999.
5. Sale, D. et al. *J Appl Physiol*, **56**, 1636–42, 1982.
6. Marsh, E. et al. *J Appl Physiol*, **51**, 160–167, 1981.
7. Mackey, D. et al. *Gait Posture*, **23**, 59-68, 2006.
8. Barrett, R. et al. *J Theor Biol*, **254**, 546-554, 2008.