Changes in the Rate of Quadriceps Force Relaxation after Prolonged Cycling

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ABSTRACT

Purpose: A reduction in the rate of force relaxation (RFR) is indicative of peripheral fatigue. Following prolonged cycling there is a combination of central and peripheral fatigue in men, but only central fatigue in women (Glace et al 2012 EJAP). The purpose of this study was to examine quadriceps RFR in response to maximal femoral nerve stimulation prior to and following prolonged cycling. It was hypothesized that RFR changes would parallel the fatigue-induced changes in quadriceps stimulated force production, and that there would be no change in RFR in women, thereby confirming the lack of peripheral fatigue in women.

Methods: Eleven men (41±3 yo, 76.0±2.3 kg, 1.81±0.21 m) and 8 women (38±3 yo, 62.3±0.32 kg, 1.64±0.32 m) cycled for 2 h at ventilatory threshold with 5, 1-min sprints interspersed, followed by a 3-km time trial. Prior to and after the prolonged cycling isometric quadriceps maximal voluntary contraction (MVC) was assessed. After the MVC a 4 s magnetic stimulation pulse train was delivered to the femoral nerve, and the stimulated quadriceps force was recorded. Absolute RFR was computed during the first 100 ms of force relaxation (N/s). Relative RFR was computed during the force relaxation from 75% to 25% of the maximal stimulated force (N/s). Time (pre vs. post) by Sex (men vs. women) mixed model ANOVA was used to assess changes in MVC, stimulated quadriceps force, and RFR (absolute and relative). Additionally, RFR was compared between subjects demonstrating a significant decline in stimulated quadriceps force (>20% force decline) and those with no force decline (≤20% force decline).

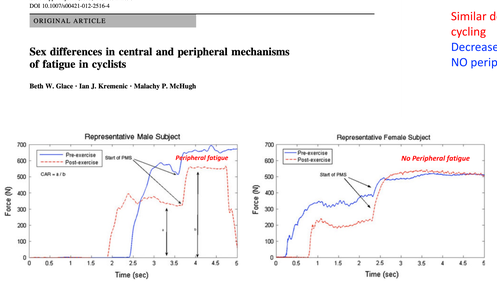
Results: MVC declined by 22±16% in women (P=0.021) and 22±17% in men (P=0.001). However, there was no decline in stimulated force in women (+2±21%, P=0.942), with a marked decline in stimulated force in men (14±19%, P=0.003; Time x Sex P=0.035). Absolute RFR did not decline in women (pre 1958±957 N/s, post 2069±852 N/s, P=0.562) but declined significantly in men (pre 2631±138 N/s, post 2229±1191 N/s, P=0.030, Time x Sex P=0.050). One woman and 7 men had significant declines in stimulated force (>20%). Absolute RFR declined by 30±17% in these 8 athletes with significant force declines, whereas absolute RFR increased by 18±21% in the 11 athletes (7 women, 4 men) with no force decline (Time x Fatigue Group P<0.001). Percent decline in absolute RFR correlated strongly with the percent decline in stimulated force (r=0.87, P<0.001), but not correlated with the decline in MVC (r=-0.07, P=0.782). Relative RFR did not decline with fatigue (Time effect P=0.927) and responses were not different between men and women (Time x Sex P=0.750). Changes in relative RFR did not differ between athletes with and without force fatigue (P=0.324) and were not correlated with force fatigue (r=0.140, P=0.567).

Conclusions: The absolute RFR data confirm the absence of peripheral fatigue in women following prolonged cycling. Changes in absolute RFR following prolonged cycling parallel the stimulated force fatigue. The lack of change in relative RFR indicates that RFR changes with fatigue are not independent of the decline in force production. (**mchugh@nismat.org**)

BACKGROUND

Central versus Peripheral Fatigue

Glace et al 2013: following cycling male cyclists had a combination of central and peripheral fatigue; female cyclists only had central fatigue (no peripheral fatigue).



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ORIGINAL ARTICLE

Sex differences in central and peripheral mechanisms of fatigue in cyclists

Beth W. Glace · Ian J. Kremenic · Malachy P. McHugh

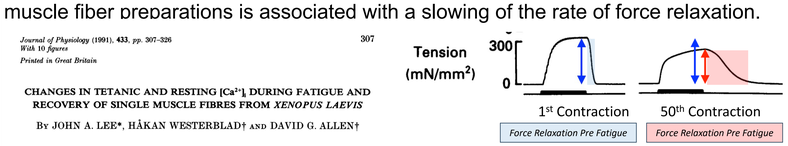
Similar decrease in MVC between men and women after cycling
Decrease in stimulated force only apparent in men
NO peripheral fatigue in women

Table 2 Results of pre- and post-cycling strength testing in men and women. Force data are normalized to body mass and reported as N/kg

	Pre-cycling		Post-cycling
VOL (N/kg)*		MVC	
Men	7.10 ± 0.45	22% lower	5.53 ± 0.45
Women	6.78 ± 0.50	17% lower	5.65 ± 0.50
PMS (N/kg)†		Stimulated Force	
Men	6.30 ± 0.83	17% lower	5.21 ± 0.71
Women	5.48 ± 0.92	1% higher	5.53 ± 0.78
AUG (N/kg)*			
Men	1.55 ± 0.37		2.37 ± 0.56
Women	1.13 ± 0.41		1.85 ± 0.62
CAR*			
Men	0.83 ± 0.04		0.71 ± 0.05
Women	0.87 ± 0.04		0.78 ± 0.06

Peripheral Fatigue

Lee et al 1991: the decrease in tetanic tension during repeated stimulations of single muscle fiber preparations is associated with a slowing of the rate of force relaxation.



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CHANGES IN TETANIC AND RESTING [Ca^{2+}]$_i$ DURING FATIGUE AND RECOVERY OF SINGLE MUSCLE FIBRES FROM *XENOPUS LAEVIS*

By JOHN A. LEE*, HÅKAN WESTERBLAD† AND DAVID G. ALLEN†

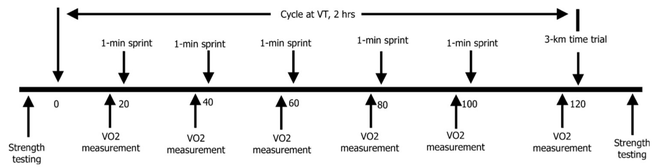
OBJECTIVES

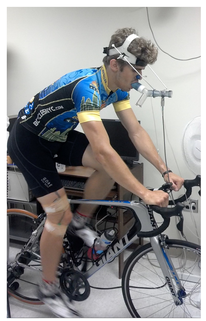
The purpose of this study was to examine quadriceps rate of force relaxation (RFR) after prolonged cycling in men and women. It was hypothesized that RFR changes would parallel quadriceps force fatigue and confirm a lack of peripheral fatigue in women.

METHODS

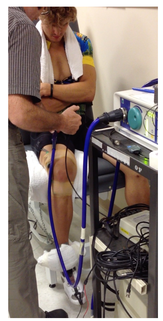
	Body mass (kg)	Height (cm)	Age (years)	VO_{2peak} (ml kg^{-1} min^{-1})	VT (% VO_{2peak})
Men	76.0 ± 2.3	180.7 ± 2.1	40.7 ± 3.1	55.9 ± 1.6	66.1 ± 0.7
Women	62.3 ± 4.4	164 ± 3.2	38.4 ± 2.9	49.3 ± 2.2	66.6 ± 1.0

Results reported as mean ± standard error





VO2 measured every 20 min

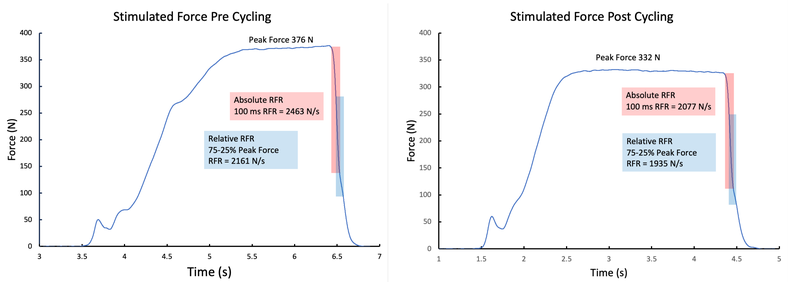


Magnetic Stimulation of Femoral Nerve

Strength Testing
1. MVC
2. Stimulated Force
3. MVC + Stimulated Force (*not reported here*)

RFR Analysis of Stimulated Force
1. Absolute RFR – force decline during first 100 ms of relaxation
2. Relative RFR – force decline from 75% to 25% of max stimulated force

See sample data below depicting absolute and relative RFRs pre and post prolonged cycling.



Sample data from a male cyclist showing calculation of absolute and relative RFR

Statistical Analyses

Time (pre vs. post) by Sex (men vs. women) mixed model ANOVA was used to assess changes in MVC, stimulated quadriceps force, and RFR (absolute and relative). Additionally, RFR was compared between subjects demonstrating a significant decline in stimulated quadriceps force (>20% force decline) and those with no force decline (≤20% force decline).

RESULTS

Differences Between Male and Female Cyclists

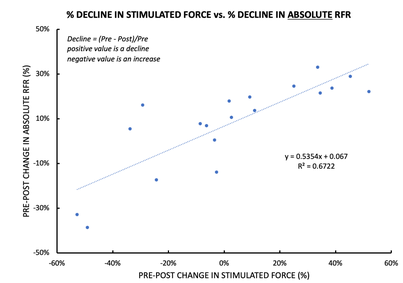
	MVC (N)			Stimulated Force (N)			Absolute RFR (N/s)			Relative RFR (N/s)		
	Pre	Post	%Diff	Pre	Post	%Diff	Pre	Post	%Diff	Pre	Post	%Diff
Men n=11	537±65	420±113**	22±17%	497±175	409±127*	14±19%	2631±1138	2229±1191	13±32%	2123±1659	2166±1938	+1±51%
Women n=8	430±122	327±75*	22±16%	352±159	350±118	+2±21%	1958±957	2069±852	+12±25%	1880±1214	1803±951	+8±35%
Sex x Fatigue		P=0.755			P=0.035			P=0.050			P=0.750	
Men vs. Women	P=0.025	P=0.059	P=0.949	P=0.199	P=0.999	P=0.090	P=0.193	P=0.751	P=0.09	P=0.730	P=0.633	P=0.745

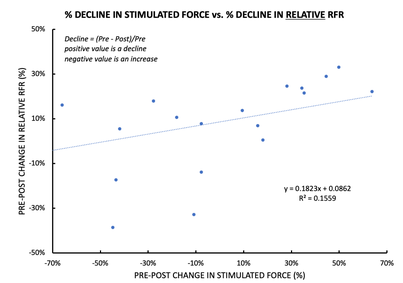
Peripheral fatigue evident in male cyclists with decrease in stimulated force and slower absolute RFR. No peripheral fatigue in female cyclists with no change in stimulated force or absolute RFR. Relative RFR did not change for male or female cyclists.
Interpretation: Decrease in absolute RFR in male cyclists and not female cyclists and no change in relative RFR for male or female cyclists indicates that fatigue-induced decrease in RFR is NOT independent of stimulated force fatigue.

Differences Between Cyclists with Peripheral Fatigue Versus Cyclists with No Peripheral Fatigue

Peripheral fatigue = decrease in stimulated force >20%

	MVC (N)			Stimulated Force (N)			Absolute RFR (N/s)			Relative RFR (N/s)		
	Pre	Post	%Diff	Pre	Post	%Diff	Pre	Post	%Diff	Pre	Post	%Diff
8 Athletes with Peripheral Fatigue	486±86	380±127*	23±19%	530±131	393±100**	24±5%	2766±829	2247±1120**	30±17%	2019±1233	1780±1865	15±56%
11 Athletes without Peripheral Fatigue	496±122	381±97**	22±15%	368±172	378±143	+4±19%	2043±1193	2245±1021	+18±21%	2023±1658	2169±1357	+1±51%
Group x Time		P=0.810			P<0.001			P<0.001			P=0.324	
Fatigue vs. No Fatigue	P=0.999	P=0.999	P=0.944	P=0.124	P=0.999	P<0.001	P=0.640	P=0.999	P<0.001	P=0.999	P=0.512	P=0.102





Cycling induced fatigue in stimulated force strongly correlated with decline in absolute RFR but not correlated with change in relative RFR.
Interpretation: RFR changes parallel force fatigue and do not provide additional information regarding peripheral fatigue.

DISCUSSION

The absolute RFR data confirm the absence of peripheral fatigue in women following prolonged cycling. Changes in absolute RFR following prolonged cycling parallel the stimulated force fatigue. The lack of change in relative RFR indicates that RFR changes with fatigue are not independent of the decline in force production.