ISB 2013
BRAZIL
24th CONGRESS OF THE INTERNATIONAL
SOCIETY OF BIOMECHANICS

EFFECTS OF WORKLOAD LEVEL IN MUSCLE ARCHITECTURE OF CYCLISTS, TRIATHLETES AND NON-ATHLETES

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SUMMARY

The aim of this study was to compare the effects of workload level in muscle architecture and muscle-tendon unit length between cyclists, triathletes and non-athletes. Three workload levels were tested (PO_{MAX}, PO_{VT2}, PO_{VT1}). Fascicle length, pennation angle, muscle thickness and muscle-tendon unit length of vastus lateralis were assessed during the propulsion phase of crank cycle. Cyclists and triathletes showed greater pennation angle and shorter fascicle length compared to non-athletes in all conditions ($p<0.05$). No differences were observed between groups for muscle thickness and muscle-tendon unit length ($p>0.05$). Cyclists and triathletes presented similar vastus lateralis architecture with differences to non-athletes potentially due to training.

Keywords

Muscle architecture, muscle-tendon unit, cyclists, triathletes

INTRODUCTION

Musculoskeletal system passive structures play an important role in force production and force transfer from the legs to the pedals during cycling [1]. Workloads and cycling experience may cause specific adaptations in their musculoskeletal system, affecting cycling performance. A previous study looked at skeletal muscle changes during pedalling at low workload level (~100 W) and pedalling cadence (40 rpm) in non-athletes [1]. Austin et al. [2] suggested that the magnitude of workload level does not affect the length of active skeletal muscle structures (i.e. fascicle length) during cycling, but it mostly changes the length of elastic components (i.e. tendons). However there is no study to date on the effects of workload level in muscle-tendon unit (i.e. length of active and passive muscle structures). Indeed, no study assessed if cyclists and triathletes would differ in terms of muscle architecture due to the different training programs between these athletes [3]. Therefore the purpose of this study was to compare the effects of workload level in muscle architecture and muscle-tendon unit, between cyclists, triathletes and non-athletes.

METHODS

Twelve cyclists (age: 28 ±6.6 years; body mass 71 ±6.8 kg; height 177 ±9.7 kg; maximal power output - PO_{Max} 375 ±30.1 W; power output at the second ventilatory threshold – PO_{VT2} 315 ±49.4 W; power output at the first ventilatory threshold – PO_{VT1} 214 ±46.6 W); ten triathletes (age: 28 ±8.8 years; body mass 77 ±9.9 kg; height 181 ±7.3 kg; PO_{Max} 386 ±45.3 W; PO_{VT2} 321 ±36.4 W; PO_{VT1} 184 ±41.3 W) and twelve non-athletes (age: 24 ±3.0 years; body mass 73 ±6.1 kg; height 175 ±5.1 kg; PO_{Max} 289 ±48.2 W; PO_{VT2} 239 ±42.5 W; PO_{VT1} 156 ±40.1 W) participated in the study.

Protocol

On the first session, anthropometric measurements (height, body mass and participants' femur length) were obtained. Participants warmed up at 150 W for 10 minutes before the test began using their own bicycle mounted on a stationary cycling trainer (Computrainer, ProLab 3D, USA) to determine maximal power (PO_{MAX}), power output at the first and second ventilatory thresholds (PO_{LV1} and PO_{LV2}, respectively). The protocol consisted of a step test with increments of 25 W every minute until exhaustion. Pedalling cadence was visually controlled close to 90 ±2 rpm. Non-athletes used a regular road bicycle with configuration adapted to their body dimensions.

On the second session (48 hrs after session 1), participants warmed up at 150 W for 10 minutes before the test began. They rode two minutes with 90 ±2 rpm of pedalling cadence at each of the following conditions:

1. Maximal power output from the incremental test
2. Power output set to second ventilatory threshold
3. Power output set to first ventilatory threshold

They were assessed using their own bicycle mounted on the stationary cycling trainer for measures of joint kinematics and muscle architecture. Each trial was separated by two minutes of rest on the bicycle and data was collected during the last 20 s for each trial.

Data collection

Right lower limb kinematics were acquired on the sagittal plane using one camera four meters from the movement plane (AVT PIKE F-032, Germany). Video was recorded at 60 frames per second via AVT ActiveCam viewer software (GmbH, Germany). Landmarks for the hip, knee and ankle joint axes were defined using reflective markers.

Muscle architecture was acquired from the right vastus lateralis using a probe (60 mm linear arrangement and 7.5 MHz frequency) connected to an ultrasound system (ALOKA, SSD 4000, Japan). The probe was positioned longitudinal to the muscle belly at 50% of participants' femur length [4].

Data analyses

Video files were digitized and automatic markers tracking was conducted in Skill Spector software (Video4Coach, Denmark) for x-y coordinates over time. Butterworth filter was set with cut-off frequency optimized to reduce signal residuals [5]. Vastus lateralis muscle-tendon unit was computed using Hawkins and Hull's model, [6] through a custom written script in MATLAB®.

Ultrasound video files were extracted from the DVDs for visual analysis of the external trigger and were edited in Virtual Dub (Avery Lee, USA). Frames were manually digitized by two experienced raters in order to assess the musculoskeletal structures within each frame. From the digitized markers, calibration factors were computed for every subject. Muscle thickness was defined as the average distance in the image's y-axis between the superficial and the deep aponeuroses. Pennation angle was computed by the average angle from the markers digitized on the fascicle and the deep aponeurosis. Fascicle length was computed by the ratio between the muscle thickness and the sin of the pennation angle and normalized by participants' femur length. All muscle architecture processing were conducted using custom written scripts in MATLAB®. Two Way ANOVA was employed for all comparisons (groups and conditions) with post-hoc LSD ($\alpha = 0.05$).

RESULTS AND DISCUSSION

Greater pennation angle and smaller fascicle length between athletes and non-athletes (Table 1) seems to be associated to their larger physiological cross-sectional area and optimal muscle length [7]. Adaptation to training potentially elicited differences between cyclists and triathletes compared to non-athletes. However, differences in training programs between cyclists and triathletes may not be sufficient to affect muscle architecture.

Higher workload level did not affect muscle architecture (Table 1), which is in line with findings from Austin et al. [2], who observed that muscle length for maximal force production is independent of workload in cycling.

CONCLUSIONS

Cyclists and triathletes have greater pennation angle and shorter fascicle length compared to non-athletes. A change in muscle architecture for athletes compared to non-athletes suggests training adaptation effects without major differences between cyclists and triathletes.

ACKNOWLEDGEMENTS

CAPES, CNPq and FINEP for financial support.

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Table 2. Mean ± sd (cv) for vastus lateralis architecture and vastus lateralis tendon unit length during the propulsion phase (0º to 180º of crank cycle) for three workload levels (maximal power output – PO_{max}, power output at the second ventilatory threshold – PO_{VT2}, and power output at the first ventilatory threshold – PO_{VT1}).

		Muscle thickness (cm)	**Pennation angle (degree)**	**Fascicle length (% femur length)**	**Muscle-tendon unit (% femur length)**
Cyclists	**PO_{Max}**	2.07 ± 0.33 (16%)	11.87± 1.98† (17%)	0.23 ± 0.04† (18%)	64.17 ± 55.32 (8%)
	PO_{VT2}	2.07 ± 0.37 (18%)	10.93± 2.01† (18%)	0.25 ± 0.04† (17%)	63.49 ± 4.27 (7%)
	PO_{VT1}	2.02 ± 0.38 (19%)	10.38± 1.69† (16%)	0.25 ± 0.05† (19%)	63.77 ± 4.70 (7%)
Triathletes	**PO_{Max}**	2.25 ± 0.36 (16%)	12.12± 1.88† (16%)	0.24 ± 0.05 (22%)	63.88 ± 6.47 (10%)
	PO_{VT2}	2.24 ± 0.33 (15%)	11.56± 1.63† (14%)	0.25 ± 0.04† (16%)	64.27 ± 5.58 (9%)
	PO_{VT1}	2.18 ± 0.35 (16%)	10.89± 1.85† (17%)	0.25 ± 0.04† (16%)	66.37 ± 5.60 (8%)
Non-athletes	**PO_{Max}**	1.98 ± 0.27 (13%)	9.61± 2.25 (23%)	0.30 ± 0.10 (35%)	63.79 ± 3.63 (6%)
	PO_{VT2}	2.01 ± 0.32 (16%)	9.31± 1.60 (17%)	0.30 ± 0.07 (22%)	62.56 ± 6.15 (10%)
	PO_{VT1}	1.95 ± 0.31 (16%)	8.87± 0.92 (10%)	0.30 ± 0.06 (20%)	65.52 ± 3.79 (6%)

† significant differences ($p<0.05$)between cyclists and triathletes to non-athletes.