

HIGH-ACCELERATION TRAINING DURING GROWTH INCREASES OPTIMAL FIBER LENGTHS IN AN AVIAN BIPEDAL MODEL

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INTRODUCTION

Previous research has shown that fiber lengths of the vastus lateralis and gastrocnemius are longer in human sprinters than in distance runners and untrained controls [1]. Longer fascicle lengths have also been associated with better performance within a group of trained sprinters [2]. In these groups, longer fiber lengths may increase muscle power and work production (independent of PCSA) by reducing fiber strain and relative velocity and thus minimizing force-length-velocity effects.

However, it is unknown if the longer fascicle lengths associated with better sprinting ability are primarily due to genetic variation or if they result from sprint training. Fascicle lengths have been shown to increase in response to stretch [3] but studies examining effects of running training are limited. One study of marathon training showed a decrease rather than an increase in gastrocnemius fiber lengths [4].

The purpose of this study was to determine if optimal muscle fiber lengths are affected by high acceleration running/jumping training during growth, when muscle plasticity may be greatest. We explored this question using a bipedal animal model, guinea fowl, that are fast-growing and amenable to training. We hypothesized that acceleration training during the animals' growth period would result in longer fascicle lengths compared to those measured in a sedentary control group.

METHODS

Guinea fowl (*Numida meleagris*) were obtained from a regional breeder (Guineafarm, OH). At 4 weeks of age, guinea fowl were split into an Exercise Group (EG; n=15) and Sedentary Group (SG; n=15). The EG were housed in a large, dual-circle pen (each 1.85 m in dia.; ~5.3 m²) with ample room for running and perching. The SG were housed in smaller pens (~1

m²) to limit movement. Birds were given food and water *ad libitum*.

Along with opportunities for spontaneous movement, the EG were exercised in two ways. An automated boom (Fig. 1) swept through the pen for 10 min h⁻¹ for 12 h per day to encourage movement. Birds were also manually exercised for 30-40 min per day for 5 days per week in which the animals accelerated in short-duration bouts of running. The SG received no external motivation for movement. The exercise protocol lasted from 4 weeks of age to 14 weeks, when birds were sacrificed. Specimens were imaged using standard x-ray for segment lengths and dual x-ray absorptiometry (DXA) for body composition. Specimens were then dissected to separate the lower limbs. Left limbs were frozen for subsequent measurement of muscle wet mass. Right limbs were fixed in 5% formalin, with joint angles set to approximate the mid-swing phase of running.

The iliotibialis lateralis pars postacetabularis muscle (ILPO; Fig. 1), a large hip and knee extensor was the focus of this study. The ILPO was chosen for initial analysis because it is a major muscle used for locomotion and has been shown to undergo substantial muscle strain during running [5]. The fixed ILPO was dissected free from the limb and photographed for measurement of fascicle pennation angle. Cranial, middle, and caudal portions were sectioned off (Fig. 1), and placed into 30% nitric acid for digestion. Digested muscles were then placed in glycerol for at least one day before small bundles of fibers were transferred to slides. Fiber lengths were measured by digitizing the fiber from high-resolution images. Laser diffraction was used to measure at least 3 different sarcomere lengths across the length of the fibers. Finally, optimal fiber lengths were calculated from the average measured sarcomere lengths per section and the known optimal sarcomere length (2.36 μ m) of guinea fowl [5]:

$$L_0 = (2.36/S_L) \cdot FL$$

where L_0 is the optimal fiber length (mm), SL is the average sarcomere length (μm) and FL is the measured fiber length (mm).

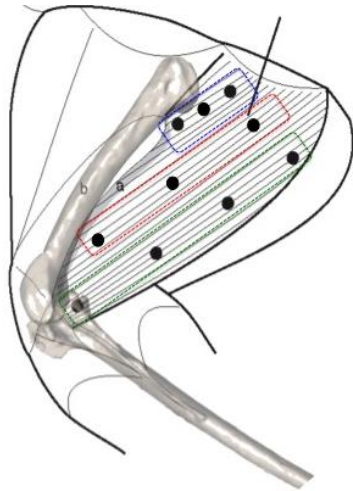


Figure 1. Schematic of the ILPO muscle and the cranial (blue), middle (red) and caudal (green) muscle sections and SL measurements (dots).

RESULTS AND DISCUSSION

The groups had similar body masses initially (4 weeks-old), but EG body mass was 10% lower than SG by week 6 and throughout the remainder of the experiment ($p < 0.05$). Body composition (percent lean mass) was similar between groups. EG had overall leg lengths 2% shorter than that of SG.

Preliminary tests ($N = 5$) revealed that wet muscle mass, PCSA, pennation angle and SL were not different between groups. Serial sarcomere number and L_0 were not statistically different between the groups, but showed a trend for increases in the cranial ILPO fibers of the EG ($p = 0.07$).

When normalized to leg length, however, the EG had significantly greater serial sarcomere numbers and longer cranial and caudal L_0 compared to the SG (Fig. 2). These results agree with previous results showing sarcomerogenesis in response to stretch training [3]. However, they contradict findings from a study of endurance training in humans [4] in which shorter

muscle fibers resulted in the gastrocnemius muscle. We interpret this result from differences in the type of training and the functional roles of the muscles studied. Endurance training may lead to adaptations for economical force production favoring short-fibered muscles such as the gastrocnemius. The high-acceleration training in the EG was, on the other hand, hypothesized to lead to longer L_0 that reduces fiber strain and velocity. These activities likely mimicked human sprint-type training as opposed to endurance training.

In conclusion, these findings offer among the first evidence that sprint training during growth may contribute to the observed differences in fiber lengths between sprinters and non-sprinters and between sprinters of varying abilities.

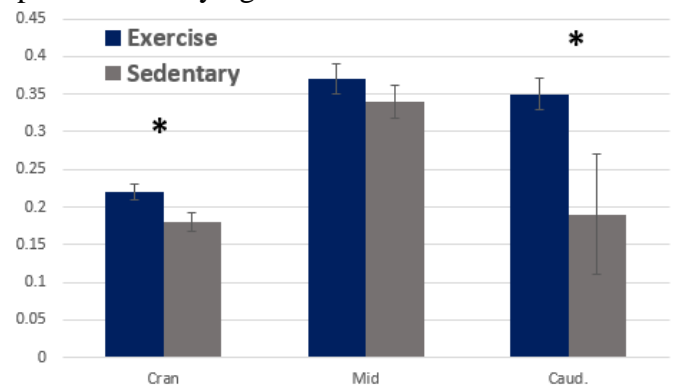


Figure 2. Fiber lengths of ILPO normalized to leg length. * $p < 0.05$ ($n = 5$ per group)

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Table 1: Stature and non-normalized muscle parameters.

	Leg Length (mm)	Muscle Mass (g)	PCSA (mm ²)	Avg. Sarcomere Length (μm)			Sarcomere Number			Optimal Fiber Length (mm)			Pennation Angle (°)		
				Cran.	Mid.	Cau.	Cran.	Mid.	Cau.	Cran.	Mid.	Cau.	Cran.	Mid.	Cau.
Exercise	264.3	12.6	146.5	2.07	2.17	2.16	24308	41384	39672	57.4	97.7	93.6	14.1	25.2	37.6
Sedentary	272.7	13.2	167.8	2.22	2.27	2.26	21152	39031	37797	49.9	92.1	89.2	14.2	25.2	32.3
p-value	0.11	0.29	0.18	0.13	0.21	0.29	0.07	0.24	0.29	0.07	0.24	0.29	0.47	0.50	0.11