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Similar changes in muscle fiber phenotype with differentiated consequences for rate of force development: Endurance versus resistance training

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ABSTRACT

Resistance training has been shown to positively affect the rate of force development (RFD) whereas there is currently no data on the effect of endurance training on RFD. Subjects completed ten weeks of either resistance training (RT, $n = 7$) or endurance cycling (END, $n = 7$). Pre and post measurements included biopsies obtained from m. vastus lateralis to quantify fiber phenotype and fiber area and isokinetic dynamometer tests to quantify maximal torque (Nm) and RFD (Nm/s) at 0–30, 0–50, 0–100 and 0–200 ms during maximal isometric contraction for both knee extensors and flexors. Both groups increased the area percentage of type IIa fibers ($p < .01$) and decreased the area percentage of type IIx fibers ($p = .05$), whereas only RT increased fiber size ($p < .05$). RT significantly increased eccentric, concentric and isometric strength for both knee extensors and flexors, whereas END did not. RT increased 200 ms RFD ($p < .01$) in knee flexor RFD and a tendency towards an increase at 100 ms ($p < .1$), whereas tendencies towards decreases were observed for the END group at 30, 50 and 100 ms ($p < .1$), resulting in RT having a higher RFD than END at post ($p < .01$). In conclusion, resistance training may be very important for maintaining RFD, whereas endurance training may negatively impact RFD.

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1. Introduction

Endurance and resistance training are two commonly applied exercise modalities utilized to achieve specific metabolic or structural muscle adaptations. Endurance training has been shown to favor elicitations of changes at the muscle level e.g., by substrate utilization (increasing beta-oxidation), mitochondrial biogenesis and glycogen storage (Hawley, 2002; Kiens, 1997; Phillips, Green, Tarnopolsky, Heigenhauser, & Grant, 1996) as well as central cardio-vascular changes leading to an increased maximal oxygen uptake (Jones & Carter, 2000). On the contrary, resistance training has been shown to strongly favor induction of muscle hypertrophy (at both whole muscle and single muscle fiber level) (Aagaard et al., 2001; Andersen & Aagaard, 2000; Vissing et al., 2008), changes in muscle architecture (Aagaard et al., 2001; Suetta et al., 2008) as well as changes in the central nervous system (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002; Aagaard et al., 2000), which collectively induce increased maximal strength and rate of force development (RFD) (Folland & Williams, 2007). Despite the many relatively divergent adaptations following the two training modalities there are also similar adaptations, one of which is increased myosin heavy chain (MHC) IIa protein expression (type IIa fibers) and decreased MHC-IIx expression (type IIx fibers) (Kraemer et al., 1995; Spangenburg & Booth, 2003) with prolonged training.

RFD is considered to, in part, be dependent on the fiber type composition of the muscle (Andersen, Andersen, Zebis, & Aagaard, 2010; Harridge et al., 1996). While RFD certainly is important for high intensity athletes (Kuitunen, Komi, & Kyrolainen, 2002; Luhtanen & Komi, 1979), it is also an important muscle performance parameter for the elderly (Hakkinen et al., 1996) and patient populations (Suetta et al., 2004). Moreover, RFD may also be an essential parameter in injury prevention, in particular in relation to hamstring muscle RFD and the protection of the anterior cruciate ligament (ACL) (Zebis, Andersen, Ellingsgaard, & Aagaard, 2011). As stated, at the single fiber level, RFD may be influenced by the fiber type composition (with type IIx showing the greatest RFD) but also the early onset neural drive (Aagaard, 2003; Aagaard et al., 2002) and, to a great extent, the fiber size, since fiber size is controlling the maximal fiber strength, thus shifting the force–time curve vertically (Andersen et al., 2010). Theoretically, the changes in MHC protein expression and hence fiber type distribution observed through both endurance and resistance training would decrease the RFD, and perhaps particularly the early RFD (30 and 50 ms after contraction onset) since these could be speculated to be highly impacted by a decreased contraction velocity. However, in the case of resistance training, increased muscle fiber size as well as increased early onset neural drive could override the decrease in RFD imposed by the MHC changes and perhaps even lead to an increased RFD as observed in some studies (Aagaard et al., 2002; Suetta et al., 2004). This is, however, not the case for endurance training, since the continuous low frequency neural stimulus implicit of endurance training is typically not observed to cause any increases in muscle fiber size (Kraemer et al., 1995). Thus, collectively, this would suggest that endurance training induces a decrease in RFD, which could be detrimental to muscular performance and injury prevention and furthermore emphasize the importance of conducting resistance training as supplement for endurance athletes (Aagaard & Andersen, 2010).

With regards to injury prevention, the above stated implication for the usage of endurance training may be particularly important for the knee flexor compartment of the thigh. Since the actions of this muscle compartment are important both in controlling knee joint stability during high force knee extension (Bencke et al., 2013) and by decreasing the strain imposed on the ACL during high force knee extensor muscle contractions (Bencke et al., 2013; Zebis, Andersen, Bencke, Kjaer, & Aagaard, 2009), any changes in muscle strength or RFD may impact performance and injury mechanisms (Zebis et al., 2011). Therefore, both the ratio of muscle strength between knee flexors and extensors (H/Q ratio), as well at the RFD ratio between the two muscle compartments (H/Q-RFD), can be speculated to serve as important muscle mechanical indicators of injury risk (Aagaard, Simonsen, Magnusson, Larsson, & Dyhre-Poulsen, 1998; Zebis et al., 2011).

Thus, the purpose of the study was to investigate (1) if 10 weeks of endurance or resistance training would induce similar changes in fiber phenotype but divergent fiber size changes, and (2) if these changes at the single fiber level could be reflected in divergent adaptations in maximal strength and RFD.

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