Eccentric Exercise Increases Satellite Cell Content in Type II Muscle Fibers

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ABSTRACT


Introduction: Satellite cells (SCs) are key among skeletal muscle tissue, growth, repair, and regeneration. A single bout of high-force eccentric exercise has been demonstrated to increase mixed muscle SC content after 1–7 d of postexercise recovery. However, little is known about fiber type–specific changes in SC content and their activation status within 24 h of postexercise recovery.

Methods: Nine recreationally active young men (23 ± 1 yr) performed 300 eccentric actions of the knee extensors on an isokinetic dynamometer. Skeletal muscle biopsies from the vastus lateralis were collected preexercise and 24 h postexercise. Muscle fiber type–specific SC content and the number of activated SCs were determined by immunohistochemical analyses.

Results: There was no difference between Type I and Type II muscle fiber SC content before exercise. SC content significantly increased 24 h postexercise in Type II muscle fibers (from 0.085 ± 0.012 to 0.133 ± 0.016 SCs per fiber, respectively; P < 0.05), whereas there was no change in Type I fibers. In accordance, activation status increased from preexercise to 24 h postexercise as demonstrated by the increase in the number of DLK1+ SCs in Type II muscle fibers (from 0.027 ± 0.008 to 0.070 ± 0.017 SCs per muscle fiber P < 0.05). Although no significant changes were observed in the number of Ki-67+ SCs, we did observe an increase in the number of proliferating cell nuclear antigen-positive SCs after 24 h of postexercise recovery.

Conclusion: A single bout of high-force eccentric exercise increases muscle fiber SC content and activation status in Type II but not Type I muscle fibers. Key Words: MUSCLE STEM CELLS, DLK1, Ki-67, PCNA

Satellite cells (SCs) are skeletal muscle precursor cells that reside between the basal lamina and the sarcolemmal membrane of their associated muscle fibers. In adult muscle, SCs are normally mitotically and metabolically quiescent (30). However, SCs can become activated in response to various stimuli, including exercise. After proliferation, SCs either differentiate donating their nuclei to existing myofibers, fuse to form new myotubes, or return to quiescence, thereby maintaining the resident basal pool of SCs through self-renewal (6,12,40). In accordance, myonuclear and SC content has been shown to increase in response to more prolonged exercise training, with a concomitant increase in muscle fiber size (15,20,28,29,34,37).

During exercise training, SC activation, proliferation, and differentiation are key regulatory steps in the expansion of the SC pool that is required to allow for skeletal muscle reconditioning. Skeletal muscle SC content has been reported to increase by 30%–150% after 24 h of recovery from a single bout of high-force eccentric exercise (7,21,26). Recent studies indicate that SC activation, proliferation, and differentiation after various stimuli are likely to occur in a fiber type–specific manner (32,34). However, it remains unknown whether acute exercise produces muscle fiber type–specific changes in SC content.

Before proliferation, SCs must become activated from the quiescent state. Recent work has provided several markers to determine the number of active SCs in human skeletal muscle tissue. Markers such as DLK1 (5,8,20,39), Ki-67 (19,24), and proliferating cell nuclear antigen (PCNA) (21) have been
applied to evaluate the activation status of the SC pool in vivo in human skeletal muscle. In line with previous comments, no data are presently available regarding potential fiber type–
specific activation of SCs during recovery from a single bout of
high-force eccentric exercise. Moreover, various types of exercise show different fiber type recruitment patterns and,
depending on the intensity of the exercise, display large dif-
fences in Type I or Type II muscle fiber recruitment (25). High-
force eccentric exercise is generally associated with
more selective Type II muscle fiber recruitment (25,26) and
Type II muscle fiber damage (9,10,38). Therefore, we tested
the hypothesis that a single bout of high-force eccentric
exercise would lead to a more specific Type II muscle fiber–
dependent increase in SC activation status and subsequent
SC enumeration.

To assess whether SCs are activated in a fiber type–specific
fashion, we enumerated SCs after a high-intensity eccentric
leg extension protocol known to selectively activate Type II
fibers to a greater degree. For the first time, we demonstrate
that high-force eccentric exercise activates SCs in a fiber type–
dependent manner, resulting in a fiber type–specific increase
in SC content after 24 h of postexercise recovery.

METHODS

Subjects. Nine healthy, active men (mean ± SD: age =
23 ± 1 yr, weight = 73 ± 2 kg, height = 1.79 ± 0.01 m) were
recruited for the study. All subjects were habitually engaged
in a variety of recreational exercise pursuits, but none were
trained in any particular sporting event. Their peak oxygen
uptake (VO₂peak), determined using online gas collection
system (Moxus Modular VO₂ System; AEI Technologies,
Inc., Pittsburgh, PA) during a ramp test to exhaustion on an
electronically braked cycle ergometer (Excalibur Sport,
Version 2.0; Lode BV, Groningen, The Netherlands), was
52 ± 3 mL·kg⁻¹·min⁻¹. Subjects were informed about the
nature and risks of the experimental procedures before written
consent was obtained. The experimental protocol was ap-
proved by the Hamilton Health Sciences/Faculty of Health
Sciences Research Ethics Board and conformed to all decla-
rations on the use of human subjects as research participants.

Experimental protocol. Subjects initially reported to
the laboratory on several occasions to become familiar with the
experimental procedures and measurement devices. At least 1 wk
after familiarization, subjects returned to the labora-
atory for a needle biopsy sample from the vastus lateralis
muscle of a randomized leg. At least 1 wk after the preexercise
(baseline) biopsy, subjects performed an acute bout of high-
force eccentric exercise using a protocol (2) previously shown
to induce ultrastructural muscle damage and reduced voli-
tional force-generating capacity. Twenty-four hours after the
cessation of exercise, subjects returned to the laboratory for a
postexercise needle biopsy.

Exercise protocol. The exercise protocol consisted of
300 high-force eccentric actions of the knee extensors per-
formed on an isokinetic dynamometer (Biodex-System 3;
Biodex Medical Systems, Inc., Shirley, NY). The protocol
was based on the work of Beaton et al. (2) and was divided
into 15 sets of 20 repetitions at a speed of 0.52 rad·s⁻¹ with
1-min rest intervals between sets.

Physical activity and nutritional controls. Subjects
maintained their habitual diet during the experiment. Diet
was recorded for 24 h before and during the preexercise
measurements, and food intake patterns were replicated be-
fore and during the postexercise measurement period. All
muscle biopsies were performed in the morning after an
overnight fast. Subjects refrained from caffeine ingestion
and alcohol for 24 h before the preexercise and postexercise
measurement periods. Subjects also refrained from using any
nonsteroidal anti-inflammatory drugs before preexercise
and postexercise measurement periods. Subjects did not per-
form any exhaustive physical activity for 48 h before the
preexercise measurements and the high-force eccentric exer-
cise trial. Preexercise and 24 h postexercise measurements for
a given subject were collected at the exact same time of day.

Muscle biopsy sampling. Muscle biopsies were ob-
tained from the middle region of the vastus lateralis muscle
15 cm above the patella and approximately 2 cm deep to the
fascia, using the percutaneous needle biopsy technique de-
scribed by Tarnopolsky et al. (33). Muscle biopsies were
taken before and 24 h after the single bout of high-force
eccentric exercise. Muscle biopsies were carefully freed
from any visible fat and blood. Thereafter, approximately
40 mg of tissue was embedded in Tissue-Tek (OCT, Tissue-
Tek; Sakura Finetek, Torrance, CA) and rapidly frozen in
liquid nitrogen cooled isopentane. Muscle biopsies were
stored at −80°C for subsequent histochemical analysis to
determine myocellular characteristics.

Immunohistochemical analysis. Using a cryostat at
−20°C, all muscle biopsy samples were oriented in a cross-
sectional direction and were cut in 5-μm sections. For each
subject, muscle samples collected at preexercise and 24 h
postexercise were mounted together on uncoated glass slides
and allowed to air-dry for 30 min at room temperature before
being stored at −20°C for subsequent analyses. Muscle
cross sections were stained for SC content and activation
status using primary antibodies against CD56 (dilution 1:40;
BD biosciences, San Jose, CA), Pax7 (neat; Developmental
Studies Hybridoma Bank, Iowa City, IA), DLK1 (monoclonal
Anti-human Pref-1/DLK1/FA1 antibody, dilution 1:50; R&D
systems, Minneapolis, MN), Ki-67 (dilution 1:200; Monoclonal
Ki-67; Biocare Medical, Concord, CA), and PCNA (ab15497,
dilution 1:200; Abcam Inc., Cambridge, MA). In addition,
cross sections were stained for muscle fiber typing using
primary antibodies against MHC-I (A4.951, dilution 1:20;
Developmental Studies Hybridoma Bank) and laminin (polyc-
clonal rabbit anti-laminin, dilution 1:50; Sigma, Zwijndrecht,
The Netherlands). Secondary antibodies used were: goat anti-
nouse IgG1/IgG (dilution 1:200, AlexaFluor488, Invitrogen;
Molecular Probes Inc., Eugene, OR), goat anti-mouse IgG2b
(Alexa555, dilution 1:500), goat anti-rabbit IgG (Alexa555,
dilution 1:500), goat anti-rabbit IgG (Alexa350, dilution
1:133), goat anti-rat IgG (Alexa350, dilution 1:133), and goat anti-rabbit biotinylated IgG (dilution 1:200; Vector Labs, Burlingame, CA) followed by streptavidin conjugated (Alexa594, dilution 1:200; Invitrogen, Canada). Nuclei were stained with 4, 6-diamidino-2-phenylindole (DAPI, 0.238 μM; Molecular Probes).

Muscle fiber type staining was performed as described previously (34–36). Briefly, after acetone fixation, muscle cross sections were incubated for 60 min at room temperature with anti-laminin and anti-MHC-I, diluted in 0.05% Tween–PBS. Slides were then washed (3 × 5 min, 1 × PBS) and incubated for 30 min at room temperature with the appropriate secondary antibodies diluted together with DAPI (0.238 μM) in 0.05% Tween–PBS. After a final wash, slides were mounted with coverslips using Mowiol (Calbiochem, Amsterdam, The Netherlands). The latter resulted in laminin stained in red, nuclei in blue, and MHC-I in green (Figs. 1 and 2).

For the muscle fiber type–specific identification and colocalization of SCs (CD56) with DLK1 or Ki-67, serial muscle cross sections of the muscle fiber type slides were fixed in acetone (5 min) and then incubated at 4°C for 24 h with anti-CD56 and DLK1 or only anti-CD56 diluted in 0.05% Tween–PBS. After incubation, slides were washed (3 × 5 min, 1 × PBS) and incubated for 30 min with the appropriate secondary antibodies diluted in 0.05% Tween–PBS. Slides were then washed and incubated at room temperature with antilaminin or antilaminin with anti-Ki-67 diluted in 0.05% Tween–PBS for 60 and 120 min, respectively. After incubation, slides were again washed and incubated for 30 min with appropriate secondary antibodies, diluted together with DAPI (0.283 μM) in 0.05% Tween–PBS. After a final wash, slides were mounted with coverslips using Mowiol. This staining procedure resulted in laminin stained in red, nuclei in blue, and CD56 in green, and DLK1 or Ki-67 in red (Figs. 1 and 2). For the identification and colocalization of mixed muscle fiber SCs (Pax7) with PCNA, muscle sections were costained with cell cycle marker PCNA. Staining procedures were as described previously (21). Briefly, after blocking (10% goat serum), sections were incubated with anti-Pax7 overnight at 4°C, washed, and then incubated with the appropriate secondary antibody. After reblocking in 5% goat serum, slides were incubated with anti-PCNA overnight. After several washes (1 × PBS), sections were incubated in the appropriate secondary antibodies for 2 h. Sections were then washed, incubated with DAPI, and then washed and mounted with a fluorescent mounting medium (Dako; Canada Inc., Canada). This staining procedure resulted in nuclei in blue, Pax7 in green, and PCNA in red (Fig. 3).

**Data analyses.** Red green blue images were recorded and processed as described previously using a Nikon E800 fluorescence microscope (Nikon Instruments Europe, Amsterdam, The Netherlands) or a Nikon Eclipse 90i Microscope (Nikon Instruments Inc., Melville, NY). All image recordings and analyses were performed by an investigator blinded to subject coding and/or study design, and staining specificity was determined with the appropriate negative controls for each stain.

Images from fiber type–stained muscle cross sections were captured at a 20× objective. Within each image, the number of fibers, the mean fiber cross-sectional area (CSA), the number of myonuclei per fiber, and the mean fiber area per nucleus (fiber CSA/#myonuclei) were assessed for Type I and Type II muscle fibers. Fiber circularity was calculated as (4π×CSA)/(perimeter)^2. No differences in fiber circularity were observed over time or between fiber types.

For mixed muscle and fiber type–specific SC analyses, images were captured at a 40× objective to allow clear SC localization. Laminin was used to visualize the basement
membrane. Fiber typing was determined by matching the serial muscle fiber type slides. SCs were determined at the periphery of each fiber and stained positive for both DNA (DAPI) and CD56 or Pax7. The number of SCs per muscle fiber was calculated for mixed muscle and Type I and Type II muscle fibers separately. To determine the activation status, the colocalization of SCs with cell cycle markers DLK1, Ki-67, or PCNA was assessed in all muscle samples. Mixed muscle DLK1+, Ki-67+, and PCNA+ SCs per muscle fiber were calculated. The proportion of SCs staining positive for DLK1, Ki-67, or PCNA (number of SCs staining positive for DLK1, Ki-67, or PCNA/number of SCs) were then calculated. In addition, the number and proportion of DLK1+ and Ki-67+ SCs were also calculated for Type I and Type II muscle fibers separately. We were unable to reliably quantify fiber type–specific SCs and Ki-67 in 1 subject and DLK1 in two subjects. An average of 424 ± 53, and 440 ± 34 muscle fibers were analyzed for muscle fiber typing, and 279 ± 77 and 296 ± 82 muscle fibers were used to assess SC content and activation status in each muscle biopsy sample collected before exercise and after 24 h of postexercise recovery.

Statistical analyses. All mixed muscle fiber data were analyzed using a two-tailed paired t-test (Sigma Stat 3.1; Systat Software, Inc., Point Richmond, CA). All fiber type–specific data were analyzed using a two-factor (fiber type × time) repeated-measures ANOVA. The level of significance for all analyses was set at $P < 0.05$, and significant interactions and main effects were subsequently analyzed using a Tukey post hoc test.

RESULTS

Muscle Fiber Type Distribution and Fiber Area

Muscle fiber type composition was 44% ± 5% Type I and 56% ± 5% Type II muscle fibers. The proportion of muscle fiber area occupied by Type I and Type II muscle fibers

<table>
<thead>
<tr>
<th>Fiber Type</th>
<th>Preexercise</th>
<th>24 h Postexercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed</td>
<td>6562 ± 473</td>
<td>7456 ± 485</td>
</tr>
<tr>
<td>Type I</td>
<td>6039 ± 478</td>
<td>7020 ± 552</td>
</tr>
<tr>
<td>Type II</td>
<td>6833 ± 611*</td>
<td>7850 ± 512*</td>
</tr>
<tr>
<td>Nuclei/fiber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>4.0 ± 0.4</td>
<td>4.8 ± 0.5</td>
</tr>
<tr>
<td>Type I</td>
<td>3.8 ± 0.5</td>
<td>4.7 ± 0.6</td>
</tr>
<tr>
<td>Type II</td>
<td>4.1 ± 0.4</td>
<td>4.9 ± 0.5</td>
</tr>
<tr>
<td>Fiber area/nucleus (μm²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>1715 ± 157</td>
<td>1635 ± 135</td>
</tr>
<tr>
<td>Type I</td>
<td>1625 ± 151</td>
<td>1541 ± 153</td>
</tr>
<tr>
<td>Type II</td>
<td>1786 ± 155</td>
<td>1702 ± 168</td>
</tr>
</tbody>
</table>

Values are presented as mean ± SE for Type I and Type II fibers and for mixed muscle fibers. CSA, muscle fiber cross-sectional area.

* Significantly different when compared with Type I muscle fiber CSA, $P < 0.05$. 

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was 37% ± 5% and 63% ± 5%, respectively. Muscle fiber area was significantly greater in Type II compared with Type I fibers (6833 ± 611 vs 6039 ± 478 μm², respectively; P < 0.05). No differences were observed in fiber type distribution and/or muscle fiber size before exercise and after 24 h of recovery from the single bout of high-force eccentric exercise (Table 1).

**Myonuclear and SC Content**

No changes in mixed muscle myonuclear content and myonuclear domain size were observed between preexercise and 24 h postexercise samples (Table 1). Furthermore, when expressed per fiber type, myonuclear content and myonuclear domain showed no significant changes over time (Table 1). For mixed muscle, the number of SCs per muscle fiber did not change after 24 h of recovery (from 0.091 ± 0.009 to 0.114 ± 0.011, respectively; P = 0.15). However, when SC content was expressed in a fiber type–specific manner, the number of SCs per Type II muscle fiber increased significantly after 24 h of recovery (from 0.085 ± 0.012 to 0.133 ± 0.016, respectively; P < 0.05; Fig. 4A), whereas no changes in Type I muscle fiber SC content were observed (Fig. 4A).

**SC Activation Status**

DLK1. Preexercise mixed muscle DLK1 expression was observed in 38% ± 9% of all SCs. The number of SCs expressing DLK1 per muscle fiber increased significantly over time (from 0.029 ± 0.006 to 0.057 ± 0.011, respectively, P < 0.05). When the number of DLK1+ SCs was expressed per muscle fiber type, no significant differences were observed between Type I and Type II muscle fibers at baseline (0.034 ± 0.007 and 0.027 ± 0.008, respectively). However, 24 h after exercise, the number of SCs expressing DLK1 had increased in the Type II muscle fibers only (from 0.027 ± 0.008 to 0.070 ± 0.017, respectively, P < 0.01; Fig. 4B).

**Ki-67.** No Ki-67+ SCs were observed in any of the preexercise samples. No significant changes in the percentage of SCs expressing Ki-67 were observed over time. In the muscle biopsy samples obtained after 24 h of postexercise recovery, Ki-67 protein expression became apparent in four of eight subjects. Three of these four subjects showed a 4%–20% increase in Ki-67+ SCs in the Type I or Type II muscle fibers, whereas one subject revealed a 42% and 78% increase in the percentage of SCs expressing Ki-67 in the Type I and Type II muscle fibers, respectively, after 24 h of postexercise recovery.

PCNA. In the preexercise samples, 13% ± 3% of the SCs expressed PCNA. The percentage of SCs stained positive for PCNA increased significantly 24 h after high-force eccentric exercise (from 13% ± 3% to 34% ± 3%; P < 0.001). In accordance, the number of PCNA+ SCs expressed per muscle fiber increased from preexercise to 24 h postexercise (0.02 ± 0.01 vs 0.07 ± 0.01, respectively; P < 0.05; Fig. 5).

**DISCUSSION**

The present study is the first to demonstrate that a single bout of high-force eccentric exercise activates SCs and augments SC content after 24 h of postexercise recovery in a muscle fiber type–specific manner. Twenty-four hours after a single session of high-force eccentric exercise, Type II muscle fiber SC activation status was increased and accompanied by a 73% ± 29% increase in SC number, whereas Type I muscle fibers showed no changes in SC activation status or content.

In the present study, we assessed the effect of a single session of high-force eccentric exercise on subsequent SC activation and enumeration in a muscle fiber type–dependent manner. We particularly selected eccentric exercise, as this has been reported to result in selective recruitment (25,26) and damage of the Type II muscle fibers (9,10,38). In the present study, mixed muscle SC content tended (P = 0.15) to increase after 24 h of postexercise recovery. Previous work has either reported a measurable (7,21,23,27) or no measurable (20) increase in SC content after 24 h of recovery from a single bout of exercise. The apparent discrepancy in the literature is likely attributed to the lack of fiber type specificity in the assessment of SC content in these studies. Many of the changes in SC content in senescent muscle (36) or after prolonged resistance-type exercise training (34,37) are fiber type specific. Therefore, it is important to consider fiber type–specific changes in SC content as demonstrated in the present investigation. Despite the lack of significant changes in mixed muscle SC content, we observed a substantial 73% ± 29% increase in Type II muscle fiber SC content (Fig. 4). In contrast, no changes could be observed
in Type I muscle fiber SC content. These findings imply that previous reported findings on the proposed effect of exercise on subsequent expansion of the SC pool may have been hampered by the lack of fiber type–dependent analyses. Clearly, the observation of such a fiber type–specific effect of eccentric exercise on the increase in the SC content punctuates the need for the acquisition of fiber type–specific data.

SC activation is a necessary component of the myogenic program before division. Therefore, in the present study, we also assessed fiber type–specific SC activation status in muscle biopsy samples taken before exercise and after 24 h of postexercise recovery. Various tissue markers have been suggested to identify the activation status of SCs by immunohistological staining (14,19–21). DLK1 is a member of the epidermal growth factor superfamily and is believed to play an important role in skeletal muscle myogenesis (8).

Previous in vivo studies in humans have already shown that DLK1 is colocalized within muscle SCs (1,18,19). In addition, we have previously reported that the number of DLK1+ SCs increases within a postexercise recovery period as short as 9 h (31). In the present study, we observed no baseline differences in the number of DLK1+ SCs between Type I and Type II muscle fibers. A significant increase in DLK1+ SCs (199% ± 88%) was observed after 24 h of postexercise recovery in the Type II muscle fibers only. The greater number of SCs expressing DLK1 agrees with the Type II muscle fiber type–specific increase in SC content.

We further characterized fiber type–specific SC activation status using cell markers Ki-67 and PCNA. Ki-67 is selectively expressed in cells during the active stages of the cell cycle (11) and has previously been successfully applied to assess SC activation status in skeletal muscle tissue (4,19,24).

These studies have demonstrated that during resting conditions, the number of proliferating SCs is quite low (19,24). In accordance, we did not find any SCs coexpressing Ki-67 in our preexercise muscle samples. To date, only a few studies have examined the number of proliferating SCs using Ki-67 after exercise (24) or electrical stimulation (19). In the present study, we observed an increase in the number of Ki-67+ SCs in four of the eight subjects in both muscle fiber types. Consequently, no significant changes in the proportion of SCs expressing Ki-67 were observed 24 h after the single bout of eccentric exercise. However, the substantial rise in both SC content and the number of DLK1+ SCs implies that the proliferative drive of the SC pool may be increased. Therefore, we also used PCNA as an alternative marker that has previously been used to identify SCs during the active stages of the cell cycle (21). To establish whether PCNA would yield different results in the present study, we contained Pax7 with PCNA. We observed that 13% ± 3% of the SCs were PCNA+ at baseline. Moreover, this proportion of PCNA+ SCs had increased significantly to 34% ± 2% after 24 h of recovery. However, the PCNA protein has a relatively long half-life time (±20 h) compared with the Ki-67 protein (60–90 min) (3,13), which will likely result in the detection of “residual” PCNA expression, even when the SCs are exiting the M Phase of the cell cycle. The latter may explain the difference between the Ki-67 and the PCNA results observed in the current study. It could be speculated that PCNA does not merely represent a marker of SCs that are proliferating but also detects those SCs that have undergone proliferation within a certain time frame before muscle biopsy collection. In fact, those SCs expressing PCNA may have already progressed further through the myogenic program and thus may include SCs returning to quiescence (i.e., self-renewal) as well as SCs progressing toward terminal differentiation. Unfortunately, as fiber type–specific staining for SCs with PCNA has so far proven unsuccessful, we did not obtain fiber type–specific data.

In the present study, we demonstrate a significant increase in SC number 24 h after performing an exercise bout composed of 300 eccentric actions. These data seem to be at odds with McKay et al. (22), who did not show a significant increase in the number of SCs in the S phase of the cell cycle until 48 h after performing a bout of resistance-type exercise (80 repetitions at 75% of 1 repetition maximum). In contrast, the presented data are supported by work from others (7,27) as well as earlier studies by McKay et al. (21,23), all of whom report significant increases in SC enumeration within 24 h after high-force eccentric exercise. Clearly, a lower-intensity concentric stimulus (75% of the subject’s 1 repetition maximum × 80 contractions [22]) may not elicit the same level of response compared with higher-intensity eccentric stimuli (100% MVC × 300 eccentric actions [21,23]). Consequently, it is more than likely that the mode of exercise, the contraction type, and the intensity level at which the exercise is performed modulate the level and timeline of postexercise SC activation and enumeration.

Recent studies clearly indicate that fiber type–specific changes in SC content and activation status are of considerable interest (31,34,37). The present study shows that in response to a single bout of high-force eccentric exercise, a substantial increase in SC activation status and a concomitant rise in SC content occur in a Type II muscle fiber–specific manner. These results support the notion that SCs respond to anabolic stimuli in line with the expected fiber type recruitment pattern (38). The latter may have important clinical relevance.
to develop more effective nutritional and/or exercise interventions in an effort to modulate muscle structure and function in both health and disease with particular relevance concerning the preferential Type II muscle fiber atrophy with aging (16,17,36).

In conclusion, a single bout of high-force eccentric exercise induces a Type II muscle fiber–specific increase in SC activation and enumeration within 24 h of postexercise recovery in young, healthy men. This study stresses the need for more fiber type–specific assessment of SC activation, proliferation, and differentiation upon various anabolic stimuli in both health and disease.

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