



Title	Differential regenerative responses of injured rat soleus muscle to icing and/or heat stress
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## 論文内容の要旨

氏 名 ( 芝 口 翼 )	
論文題名	Differential regenerative responses of injured rat soleus muscle to icing and/or heat stress (アイシングと熱ストレスに対する損傷したラットヒラメ筋の異なる再生応答)
論文内容の要旨	
<p>In the area of sports medicine, icing has been widely accepted as a common first-aid treatment for sports injuries, including skeletal muscle injury. However, some researchers recently demonstrated that icing immediately after skeletal muscle injury delayed and impaired muscle regeneration (Takagi et al. 2011; Ito et al. 2013). On the other hand, several studies reported that application of heat stress to injured skeletal muscle facilitated muscle regeneration (Kojima et al. 2007; Oishi et al. 2009; Takeuchi et al. 2014; Oishi et al. 2015). Although the precise mechanisms of these different responses of injured skeletal muscle, particularly in slow soleus muscle, to icing and heat stress are still unclear, these findings indicate a need for reconsidering the treatment of skeletal muscle injury. Therefore, in the part 1 experiment, I compared the effects of icing with those of heat stress on the induction of regeneration and/or fibrosis of injured rat slow soleus muscle in the same experiment. Although the recovery of muscle mass, protein content, and muscle fiber size in regenerating soleus muscle was not affected by icing applied immediately after the injury, the icing treatment accelerated and enhanced the injury-related development of fibrosis. This treatment also delayed the timing of disappearance of transforming growth factor-<math>\beta</math> in the regenerating muscle. In contrast, repeated heat stress to the injured soleus facilitated the recovery of muscle mass, protein content, and muscle fiber size. Moreover, the injury-related development of fibrosis was inhibited by the application of heat stress, and the fibrotic area was also significantly lower in heat-stressed than icing-treated animals at the later phases of regeneration. These heat stress-associated promotions of soleus muscle regeneration may be attributed to enhanced macrophage infiltration, proliferation and differentiation of muscle satellite cells, and heat shock protein 72 expression. In the part 2 experiment, I studied the changes of myosin heavy chain (MyHC) profiles in regenerating soleus muscle in response to icing and heat stress. As a result, I revealed that the recovery of MyHC profiles toward the normal control level in the regenerating soleus was partially delayed by icing but promoted by heat stress at both whole muscle and individual muscle fiber levels. Thus, these results strongly suggest that icing may not be the optimal first-aid treatment for skeletal muscle injury, particularly as regarding qualitative recoveries of the injured muscle. However, it is suggested that heat stress may be more effective therapeutic approach leading to enhanced both quantitative and qualitative recoveries of injured skeletal muscle than icing.</p>	

## 論文審査の結果の要旨及び担当者

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## 論文審査の結果の要旨

申請者は、損傷した骨格筋の再生と筋固有の特性の回復を促進させる方策として、冷却（アイシング）と温熱いずれの場合が筋損傷後の処置として妥当であるかについて、ラットの抗重力筋で代表的な遅筋の一つであるヒラメ筋を対象に研究を行った。その結果、筋損傷後のアイシングは、ヒラメ筋の線維化の進行とその程度を促進するだけでなく、筋線維組成の正常な分布への回復を遅延化させることを示した。また、無処置やアイシングの場合と比較して、筋損傷後の間欠的な温熱刺激は、ヒラメ筋の再生筋線維サイズの回復や筋線維組成の正常な分布への回復を促進するのみならず、線維化も抑制することを明らかにした。

これらの研究成果は、スポーツ医学やリハビリテーションの分野において重要な知見をもたらすものがある。また、研究成果の一部は既に原著論文として出版が決まっている。以上、本論文はオリジナリティーのある研究であり、博士論文として十分に値するものである。