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学 位 論 文 題 名	Acute effects of static versus dynamic stretching on muscle hardness using ultrasound strain elastography and isokinetic peak torque of the gastrocnemius muscle （腓腹筋に対するスタティックストレッチングおよびダイナミクストレッチングが超音波ストレインエラストグラフィにより計測される筋硬度と等速性ピークトルクに与える急性効果）
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論 文 内 容 の 要 旨

Purpose

Dynamic stretching (DS) improvements in performance that may be expected to apply for elderly people's health promotion and patients in physical therapy. Almost of all previous studies had conducted DS in over 50 beats/min speed of joint movements, however this quick joint movement will be difficult to apply for elderly people and persons with disabilities. Therefore, we thought it is important to compere effects of general 50 beats/min speed DS and slow 10 beats/min speed DS.

Ultrasound elastography is a noninvasive technique developed recently for the measurement of tissue hardness within the body. Nakamura et al. (2014) used ultrasound elastography and investigated the acute change of muscle hardness after static stretching (SS) of the gastrocnemius muscle. They reported a significant decrease in medias gastrocnemius (MG) muscle hardness immediately after SS. However, there are no published data of DS studies using ultrasound elastography for measuring acute changes in muscle hardness after intervention.

Therefore, the purpose of this study was to investigate the acute effects of SS, general-speed DS (GDS; 50 beats/min) and slow-speed DS (SDS; 10 beats/min) of the gastrocnemius muscle on muscle hardness measured by RTE and on isokinetic plantarflexion peak torque.

Subjects and Methods

Ten males and Ten females (ages 21-34 years) participated in this crossover study. All subjects participated in three stretching conditions and one control condition, which were randomly allocated and conducted on separate days with at least 24 h recovery between each intervention. The SS condition was held for 60 s, the GDS condition was performed as 12 repetitions at a velocity of 50 beats/min, the SDS condition was performed as 12 repetitions at a velocity of 10 beats/min and the control condition was at rest for 60 s. MG muscle hardness, ankle passive dorsiflexion range of motion, and isokinetic plantarflexion peak torque were measured. Measurements were conducted before and after each of the three conditions. Repeated measure ANOVA [Subjects × Factors (pre-SS vs. post-SS vs. pre-GDS vs. post-GDS vs. pre-SDS vs. post-SDS vs. pre-CON vs. post-CON)] followed by the Bonferroni multiple comparison test was used to statistical analyze muscle hardness, range of motion, and isokinetic peak torque values.

Results

Muscle hardness decreased in the SS condition ($P < 0.01$, $r = 0.80$), the GDS condition (P <0.01 r = 0.79) and the SDS condition ($P < 0.01$, $r = 0.80$). Range of motion increased in the SS condition ($P < 0.01$, $r = 0.86$), the GDS condition (P < 0.01, r = 0.84) and the SDS condition ($P < 0.01$, $r = 0.85$). The control condition showed no changes in muscle hardness and range of motion after the intervention. Isokinetic peak torque decreased in the SS ($P < 0.01$, $r = 0.70$), but not in the GDS, SDS and control conditions.

Discussion

The acute effects of SS and DS on muscle hardness of the MG muscle were investigated using RTE. This study is the first to present the acute changes in muscle hardness after DS using ultrasound elastography and also compere general-speed DS with slow-speed DS (50 beats/min speed vs. 20 beats/min speed). The present results indicated that there was a significant decrease in muscle hardness after SS, GDS and SDS ($P < 0.01$, in all conditions), and no significant difference between SS and both DS. GDS and SDS, both of which provided similar decreases to SS for muscle hardness by these DS-induced mechanisms. The mechanism underlying the decrease in muscle hardness after

SS may be decreased neuromuscular activation (i.e. α motor neurons) and change in the properties of the intramuscular connective tissue, rather than muscle fiber lengthening (Ryan et al. 2008). The mechanisms after DS were increases in physiological temperature and reciprocal inhibition by voluntary contraction of the antagonist (Behm and Chaouachi 2011).

In addition, the present results showed that SS, GDS and SDS induced a significant increase in ROM ($P < 0.01$, in all conditions), with no significant difference between SS and both DS ($P = 1.00$, in both conditions). The acute increases in ROM have been considered to be effective in improving the flexibility of muscle tissue (O'Sullivan et al. 2009). Hence, ROM changes after SS and DS may reflect changes in muscle hardness after SS and DS.

For plantarflexion peak torque, the results of the present study showed that SS decreased isokinetic peak torque of the plantar flexor muscles ($P < 0.01$), but there were no changes in strength as a result of GDS and SDS (P = 1.00, both of conditions). These results are consistent with previous studies that reported acute decreases in muscle strength after SS, which has since been termed the stretching-induced deficit (Behm and Chaouachi 2011). Two hypotheses have been proposed to explain the stretching-induced deficit. They are mechanical factors, such as decreases in muscle hardness and increases in the resting length of sarcomeres that alter the length-tension relationship of a muscle, and neuromuscular factors, such as altered motor control strategies and/or reflex sensitivity. With DS, on the other hand, previous studies (Behm and Chaouachi 2011) reported the mechanisms of DS-induced positive effects, with elevations of muscle and body temperatures, post-activation potentiation which is the transient improvement of muscular performance after a previous contraction in the dynamically stretched muscle (Houston and Grange 1990), stimulation of the nervous system, and/or decreased inhibition of antagonist muscles.

Collectivity, these results indicated that both general-speed and slow-speed DS decrease muscle hardness and expand ROM as well as SS, without loss in muscle strength than SS. The mechanism of DS-induced positive effects may less detrimental to muscle force production than SS. Therefore, regardless of whether the speed was general or slow, DS may have greater applicability than SS to expand flexibility without decreasing muscle strength. For example, athletes should incorporate a DS into their warm-ups before exercise. Moreover, previous study showed that poor flexibility increases arterial stiffness in wide generations (Nishiwaki et al. 2014). Both general and/or slow-speed DS may be useful for physicians in medical rehabilitation and health promotion, improving muscle hardness, conditions and ROM, especially in this slow joint movement expected to apply for elderly people and persons with disabilities.

Conclusions

These results suggest that dynamic stretching may have greater applicability than SS to expand flexibility without decreasing muscle strength. DS may be useful for medical rehabilitation and health promotion improving muscle hardness and conditions, especially in slow-speed DS expected to apply for elderly people and persons with disabilities.

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論文審査結果の要旨

要旨：本研究はスタティックストレッチング（SS）と一般的速度のダイナミックング（GDS）およびゆっくりとしたダイナミックストレッチング（SDS）を腓腹筋に実施し，超音波エラストグラフィによる筋硬度と底屈ピークトルクの即時効果を比較した。その結果 GDS と SDS は，SS と同様に筋硬度を低下させたが，SS のような筋力低下を認めなかった点において，SS 以上の優位性を有してい

ると考えられた。

　斬新さと重要性：ダイナミックストレッチング（DS）の基礎的な研究として，超音波エラストグラフィを用いて筋硬度を調べた初めての研究である。また，ゆっくりとしたDSでも筋力低下を来さずにストレッチ効果があることを証明した本研究は，今後疾患を持った高齢者への臨床応用を期待できる点でも斬新かつ重要である。

　研究方法の正確性：超音波エラストグラフィを用いることで筋硬度を客観的に評価した。表現の明瞭性：本研究論文は，簡潔明瞭に書かれている。

　以上述べたように，本論文は学位を授与するのに十分値する研究と判断された。