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# Intramuscular Tenderness Mapping and Muscle Fiber Directions of Small Muscles in the Beef Round

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## Summary

The intramuscular tenderness variation of *m. pectineus* (PT), *m. sartorius* (SR), *m. gracilis* (GL), *m. vastus intermedius* (VI), and *m. vastus medialis* (VM) was investigated. The PT, SR, VI, and VM muscles ( $n=10$  each) were grilled as whole muscles, whereas the GL was grilled after cutting into anterior and posterior regions. Grilled muscles were cut into equal size sections perpendicular to the long axis from proximal to distal. Cores were prepared from each section and Warner-Bratzler shear force (WBSF) was measured. The overall mean WBSF values for PT, SR, VI, GL, and VM were 8.29, 9.79, 10.54, 10.47, and 9.35 lb, respectively. The muscle fiber orientations of PT and VI were bipennate, GL and VM were unipennate, and SR was fusiform. Based on the WBSF ratings and muscle fiber orientation, all of these small muscles are relatively tender (especially the PT), and they could be merchandized as single-muscle steaks or medallions.

## Introduction

About one-fifth (about 22%) of the weight of a beef carcass is represented by the round. Most large muscles of a beef carcass are located in the round, and they are known to be the least tender muscles of the carcass. However, in the last few decades, the wholesale price of beef round has been significantly increasing. Characterization of muscles in the beef round is necessary to evaluate value-added strategies. While tenderness differences among major muscles of the beef round and chuck and their intramuscular tenderness variations have

been well documented, there is little, if any, information on tenderness variation of small muscles in the beef round. In addition, the knowledge of muscle fiber orientation is important during meat fabrication so that muscles can be cut into steaks or pieces across the grain to improve tenderness. Therefore, this research was conducted to investigate the intramuscular tenderness variation and muscle fiber orientation of small muscles in the beef round, including *m. pectineus* (PT), *m. sartorius* (SR), *m. gracilis* (GL), *m. vastus intermedius* (VI), and *m. vastus medialis* (VM).

## Procedure

Ten each of the PT, ST, GL, VI, and VM were purchased as USDA Choice boxed beef subprimals, aged for about 14 days from boxed date, and frozen after being vacuum-packaged. The PT, ST, and GL were fabricated from beef inside round cap (IMPS #168; NAMP, 2007) and VI and VM were obtained from beef round, knuckle peeled (IMPS #167A; NAMP, 2007). During fabrication, the anterior and distal domains of each muscle were appropriately tracked.

Whole muscles were thawed at 39°F for 24 hours. Anterior or distal domains of each muscle were tracked. The PT, SR, VI, and VM were grilled on a Hamilton Beach indoor-outdoor grill (Model 31605A, Proctor-Silex Inc., Washington, N.C.), turning over once at 95°F, until they reached an internal temperature of 160°F. Prior to grilling, the GL was cut into anterior and posterior sides to have portions of equal thickness. Internal temperature was monitored using a type T thermocouple inserted into the geometric center of each muscle. Grilled muscles were cooled at 39°F for 24 hours, then allowed to reach room temperature. The PT, SR, and VM were cut into proximal and distal zones and each distal and proximal end was cut into

inch-thick portions perpendicular to the long axis of the muscle. Each anterior and posterior side of the GL was divided into proximal and distal zones. Medial and lateral sides of VI were divided into sections from proximal to distal. From each section of PT, SR, VM, GL, and VI muscles, cores with 0.5 in diameter were removed parallel to the muscle fiber arrangement using a drill press. Cores were sheared on an Instron universal testing machine (Model 55R1123, Canton, Mass.) with a Warner-Bratzler shear attachment. An average of the peak Warner-Bratzler shear force (WBSF) for each muscle piece was calculated. Before making cores from each piece of muscle, the visible muscle fiber angle at the cutting surface was measured using a protractor from the proximal to the distal end of each muscle in order to illustrate the muscle fiber orientation.

Warner-Bratzler shear force values were analyzed by using the GLIMMIX procedure of SAS (version 9.1) with a model including zone (proximal to distal) of PT, ST, and VT muscles. The zonal difference (proximal vs. distal) of each muscle was analyzed using CONTRAST statements. For GL and VI muscles, zone (distal to proximal), side (anterior and posterior), and their interactions were included in the model. The zonal difference (proximal vs. distal) and side difference (anterior vs. posterior or medial vs. lateral) of GL and VI muscles were analyzed using CONTRAST statements of SAS. Least square means were calculated for each section using the LSMEANS of SAS. Mean separation was performed by the DIFF and LINES options of SAS at  $P < 0.05$ .

## Results

The mean WBSF values of PT, SR, GL, VI, and VM were 8.29, 9.79, 10.54, 10.47, and 9.35 lb, respectively. The

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WBSF values for tenderness levels were investigated and reported as follows: “tender” = < 8.49 lb, “intermediate” = 8.49 to 10.78 lb, and “tough” = > 10.78 lb (Von Seggern et al., 2005 *Meat Science*, 71: 39-51). According to this classification, PT was “tender,” and SR, GL, VI and VM were “intermediate.”

There were no significant tenderness variations among sections of the PT (Figure 1a). However, the distal end of the PT muscle was significantly tougher ( $P = 0.05$ ) than the proximal end (Table 1). The distal end of the PT is narrow and attaches to the femur. Lawrie (*Meat Science 6<sup>th</sup> edition*, Woodhead Publishing Ltd, Cambridge, England) mentioned that muscle fibers taper at the end and continue with non-contractile connective tissues in order to attach to the bones; therefore, muscles are tough at the distal end. The muscle fibers were attached to the connective tissue located at middle of the proximal end of the muscle producing a bipennate muscle fiber orientation. The muscle fiber angle changed at  $110^\circ$  to  $50^\circ$  from proximal to the distal end (Figure 1b). Based on its tenderness and muscle fiber orientation, PT should be grilled as a whole muscle and cut into medallions along the muscle or cut into medallions prior to grilling.

The tenderness of the SR significantly ( $P = 0.01$ ) varied along the muscle (Figure 2a). As shown in Table 1, the proximal end was tougher than the distal end of ST muscle ( $P = 0.04$ ). This is more likely due to tapering of the muscle at the proximal end. The muscle fibers of SR run parallel to the long axis of the muscle producing a fusiform muscle fiber orientation (Figure 2b). The SR could be grilled as a whole muscle and cut into medallions or cut into medallions prior to grilling.

As shown in Table 1, the tenderness of the proximal and distal ends of the VM were similar ( $P = 0.12$ ). However, the most distal region of the

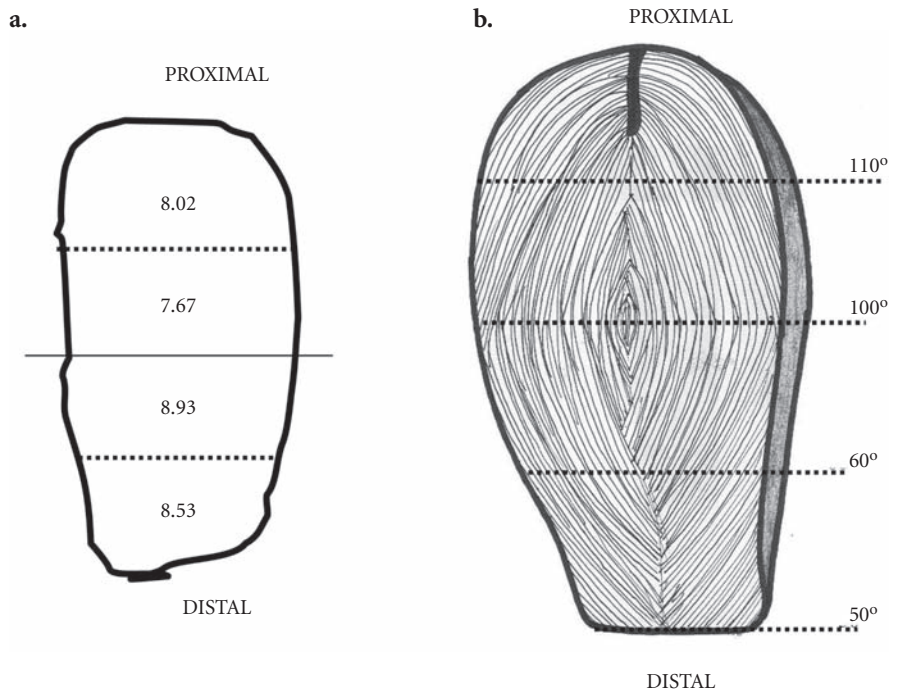


Figure 1. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. pectineus* ( $P = 0.13$ ). b. Muscle fiber orientation of *m. pectineus* on the longitudinal cross section of the muscle. <sup>a,b</sup>Means in the same figure with different superscripts significantly differ ( $P < 0.05$ ).

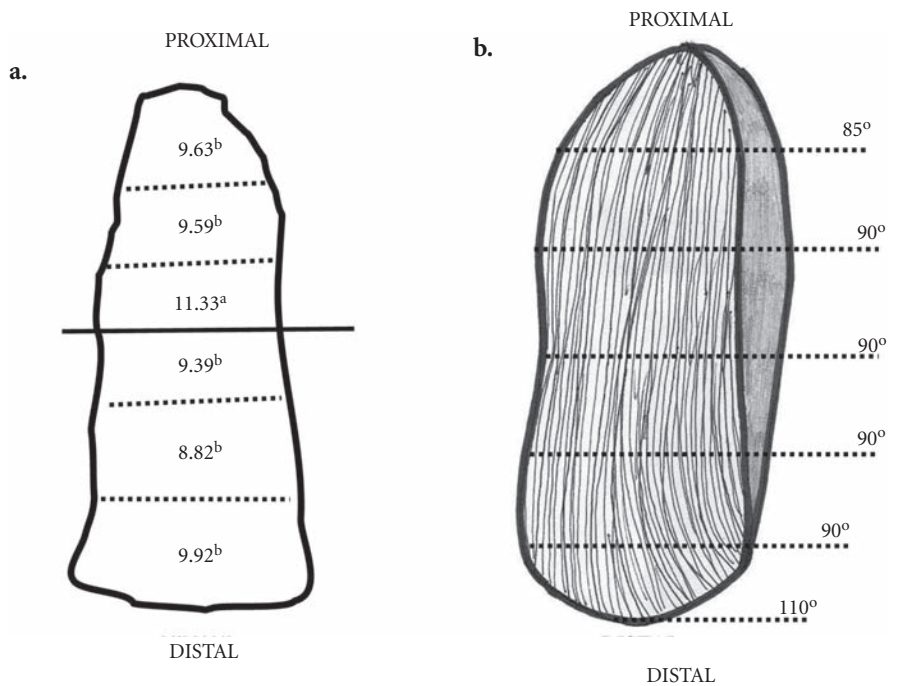


Figure 2. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. sartorius* ( $P = 0.01$ ). b. Muscle fiber orientation of *m. sartorius* on the longitudinal cross section of the muscle. <sup>a,b</sup>Means in the same figure with different superscripts significantly differ ( $P < 0.05$ ).

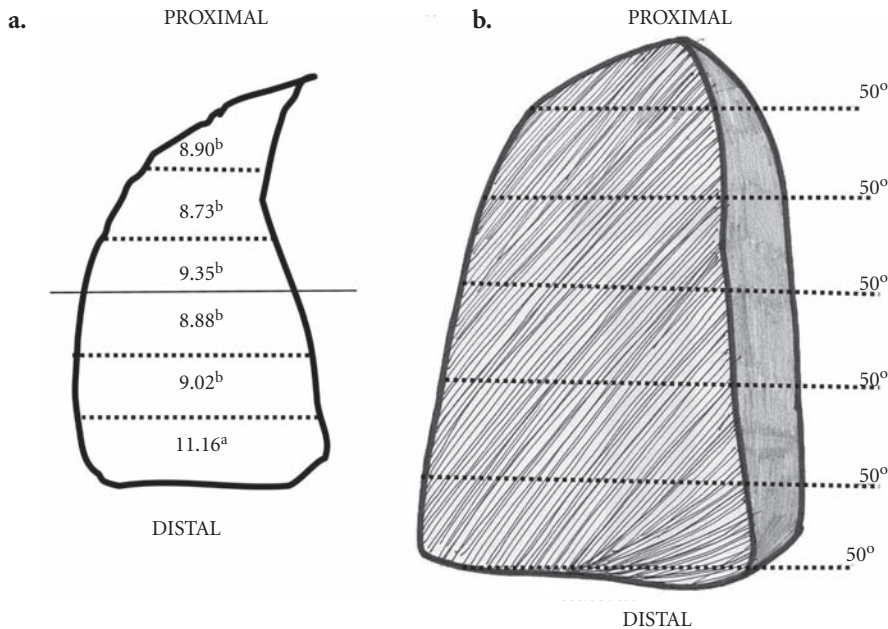


**Table 1. Least square mean Warner-Bratzler shear force values (lb) of zones, sides, and regions of small muscles in beef round.**

Muscle	Zone			Side			Region		
	Proximal	Distal	P-value	Medial	Lateral	P-value	Anterior	Posterior	P-value
<i>m. pectineus</i>	7.85 <sup>b</sup>	8.73 <sup>a</sup>	0.03	NA	NA	NA	NA	NA	NA
<i>m. sartorius</i>	10.19 <sup>a</sup>	9.37 <sup>b</sup>	0.04	NA	NA	NA	NA	NA	NA
<i>m. v. medialis</i>	8.99	9.68	0.12	NA	NA	NA	NA	NA	NA
<i>m. v. intermedius</i>	9.47 <sup>b</sup>	11.6 <sup>a</sup>	< .0001	8.93 <sup>b</sup>	12.15 <sup>a</sup>	< .0001	NA	NA	NA
<i>m. gracilis</i>	10.27	10.67	0.08	NA	NA	NA	10.25	10.69	0.07

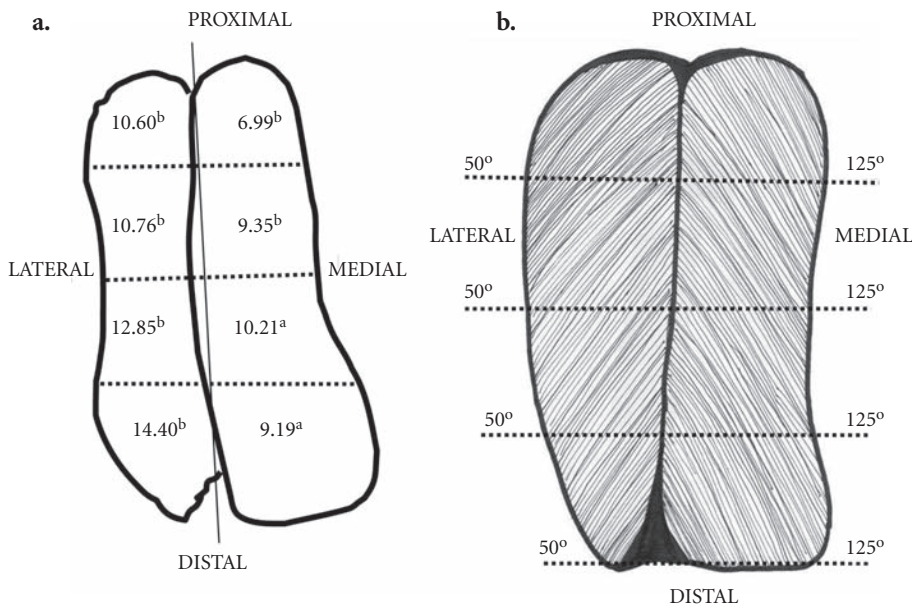
NA – not applicable

<sup>a,b</sup>Means in the same row under each domain with different superscripts significantly differ ( $P < 0.05$ ).



**Figure 3. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. vastus medialis* ( $P = 0.02$ ). b. Muscle fiber orientation of *m. vastus medialis* on the longitudinal cross section of the muscle.**

<sup>a,b</sup>Means in the same figure with different superscripts significantly differ ( $P < 0.05$ ).



**Figure 4. a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. vastus intermedius* ( $P = 0.04$ ). b. Muscle fiber orientation of *m. vastus intermedius* on the longitudinal cross section of the muscle.**

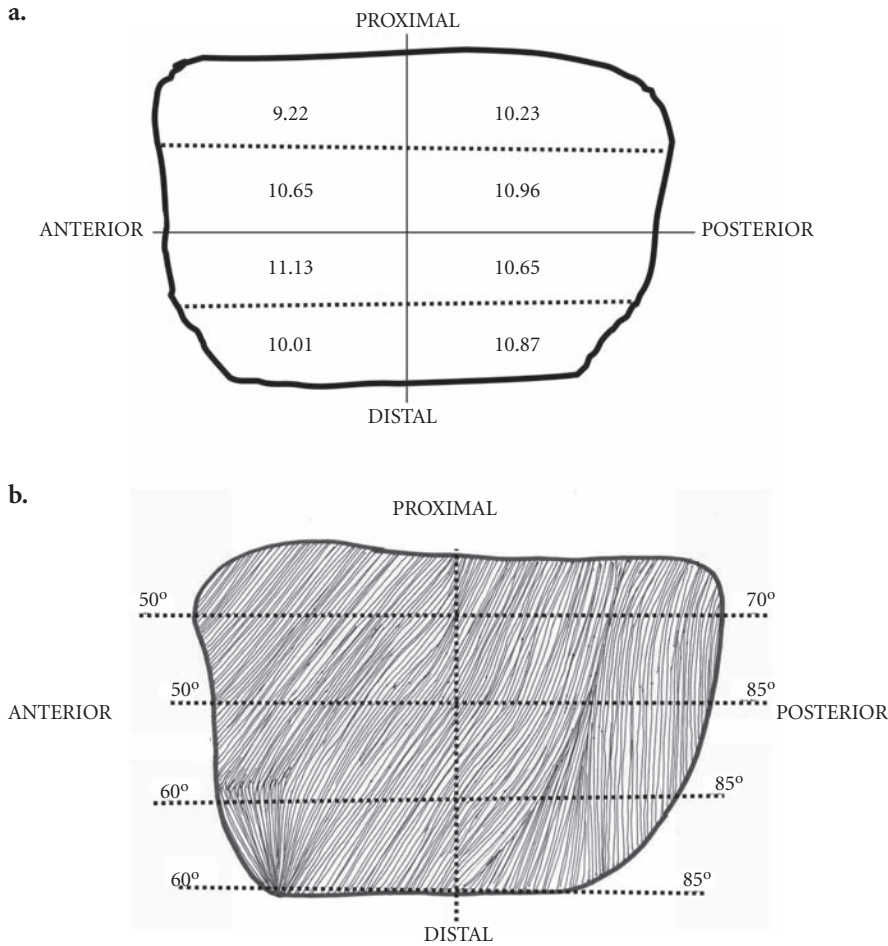
<sup>a,b</sup>Means in the same figure with different superscripts significantly differ ( $P < 0.05$ ).

muscle was significantly tougher than the rest of the muscle (Figure 3a). The fiber orientation of VM was unipennate with an angle of 50° from the proximal to the distal end (Figure 3b). Therefore, the VM could be cut into medallions angular to the long axis of the muscle.

The tenderness of the VI muscle differed along the muscle (Figure 4a). The most lateral and distal region of the muscle was significantly tougher than the rest. The most tender region of the VI muscle was the most proximal and medial region (Figure 4a). The distal region of the muscle was significantly tougher ( $P < 0.0001$ ) than the proximal region (Table 1). In addition, the medial side of the VI was significantly more tender ( $P < 0.0001$ ) than the lateral side (Table 1). The VI had the bipennate muscle fiber orientation (Figure 4b). Muscle fibers extended medially and laterally from both sides of the tendon, which runs along the muscle between the medial and lateral portions of the muscle. In the medial side, the muscle fibers made a 125° angle with the tendon, whereas muscle fibers in the lateral side made a 50° angle with the tendon. The lateral and the medial portions of the muscle should be separated before making medallions. Medallion steaks could be made angular to the long axis of the lateral and medial sides in order to increase the size of the medallions.

There were no tenderness variations in the distal and proximal or anterior or posterior sections of the GL (Table 1). However, the most proximal section of the muscle was more tender than the rest (Figure 5a;  $P = 0.002$ ). The muscle fiber orienta-

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**Figure 5.** a. Least square mean Warner-Bratzler shear force values (lb) of each domain of *m. gracilis* ( $P = 0.08$ ). b. Muscle fiber orientation of *m. gracilis* on the longitudinal cross section of the muscle.

tion of the GL was unipennate. In the posterior side of the muscle, muscle fibers were running angularly making  $70^\circ$  to  $85^\circ$  angles, whereas muscle fiber angles were changing from  $50^\circ$  to  $60^\circ$  in the anterior side toward the distal end of the muscle (Figure 5b). Prior to grilling, GL should be separated into the anterior and posterior regions. After grilling, steaks should be made perpendicular to the long axis of both portions of the muscle.

Despite tenderness differences along the muscles, the average Warner-Bratzler shear force testing showed that *m. pectineus* was tender and *m. sartorius*, *m. vastus medialis*, *m. gracilis* and *m. vastus intermedius* were intermediate tender muscles. Therefore, *m. pectineus*, *m. sartorius*, *m. vastus medialis*, *m. gracilis* and *m. vastus intermedius* can be marketed as single-muscle steaks or medallions.

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