Video Article

Human Skeletal Muscle Biopsy Procedures Using the Modified Bergström Technique

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Abstract

The percutaneous biopsy technique enables researchers and clinicians to collect skeletal muscle tissue samples. The technique is safe and highly effective. This video describes the percutaneous biopsy technique using a modified Bergström needle to obtain skeletal muscle tissue samples from the vastus lateralis of human subjects. The Bergström needle consists of an outer cannula with a small opening ('window') at the side of the tip and an inner trocar with a cutting blade at the distal end. Under local anesthesia and aseptic conditions, the needle is advanced into the skeletal muscle through an incision in the skin, subcutaneous tissue, and fascia. Next, suction is applied to the inner trocar, the outer trocar is pulled back, skeletal muscle tissue is drawn into the window of the outer cannula by the suction, and the inner trocar is rapidly closed, thus cutting or clipping the skeletal muscle tissue sample. The needle is rotated 90° and another cut is made. This process may be repeated three more times. This multiple cutting technique typically produces a sample of 100-200 mg or more in healthy subjects and can be done immediately before, during, and after a bout of exercise or other intervention. Following post-biopsy dressing of the incision site, subjects typically resume their activities of daily living right away and can fully participate in vigorous physical activity within 48-72 hr. Subjects should avoid heavy resistance exercise for 48 hr to reduce the risk of herniation of the muscle through the incision in the fascia.

Video Link

The video component of this article can be found at http://www.jove.com/video/51812/

Introduction

The percutaneous or 'semi-open' biopsy technique is used to obtain skeletal muscle tissue specimens from human patients and research subjects. Duchenne (1806-1875) is credited as the first to construct a needle with a trocar to obtain skeletal muscle from living subjects through percutaneous biopsy[1]. In the 1960's, Bergström introduced a percutaneous biopsy needle similar to that described by Duchenne[2-4]. Twenty years later, Evans *et al.*[5] modified the technique by applying suction through the cutting trocar of the Bergström needle. This modification can enhance the yield of tissue 3- to 5-fold[6,7] and is employed in clinical and biomedical research settings. This technique has and will continue to foster the diagnosis of myopathies and our understanding of the structure and function of skeletal muscle.

The percutaneous muscle biopsy technique is straightforward. When done correctly, with strict adherence to aseptic technique, the associated risks are minimal. The muscle biopsy procedure is regarded as an investigational tool for research projects. Some academic institutions allow trained faculty researchers with a Ph.D., with direct physician oversight, to obtain muscle biopsies and others require a board-certified physician to perform the technique. The ASU biopsy team has successfully performed over 1,600 muscle biopsies during the past 13 years[8-15]. The purpose of this video is to describe the modified Bergström needle percutaneous muscle biopsy technique[5] to obtain skeletal muscle tissue samples from the vastus lateralis of human subjects.

Protocol

The skeletal muscle procedure as described follows the guidelines of the Appalachian State University Institutional Review Board.

NOTE: The team consists of an operator (Ph.D. or M.D. trained in the biopsy technique), and at least one, but ideally, three or more technicians. The operator is responsible for conducting and overseeing all aspects of the skeletal muscle biopsy procedure. One technician (technician #1) is immediately responsible for assisting the operator with all aspects of muscle extraction. This includes being the "non-sterile hands" and applying suction with a sterile syringe. A second technician (technician #2) engages in conversation with subject and massages the subject's opposite leg during procedure to minimize the subject's anxiety. The third technician (technician #3) is responsible for handling and processing the skeletal

muscle sample. Downstream analytical measures dictate how many additional technicians are required for processing/preparing the skeletal muscle sample.

1. Subject Preparation

1. Gather, prepare, and organize the materials specified for the muscle biopsy procedure (**Table 1**). Decontaminate and sterilize the Bergström needle (outer cannula and inner trocar) and the plunger according to standard practice[16].
2. Review the consent form with the subject. The skeletal muscle biopsy portion of the Consent to Participate form used at Appalachian State University is provided in online supplement 1.
    1. Talk to the subject about the general aspects of the muscle biopsy procedure with a focus on possible risks of the procedure, skin preparation, application of the anesthetic, typical sensations. Instruct the subject to carefully read the Consent to Participate form and sign it to confirm that the study design and procedures are understood.
3. Confirm that the subject is not allergic to "___caine"-type medications (*e.g.*, lidocaine).
4. Instruct the subject to lie supine on a padded table with the thigh exposed. Place two disposable absorbent underpads with plastic backing under the subject's leg. Position the leg in a relaxed manner with a small towel roll under the heel, such that the knee is fully extended (elevated ~1 cm), thus placing the vastus lateralis in a shortened position.
5. Have the operator instruct the subject to momentarily contract the exposed thigh muscle so that the biopsy site can be visualized. Note: The vastus lateralis biopsy site is just anterior to the fascia lata (illiotibial band), approximately one-third of the distance between the top of the patella and the greater trochanter[7].
6. Have the operator mark just below (~0.5 cm) the incision site with a fine point permanent marker.
7. Have the operator determine the approximate skinfold thickness by pinching the skinfold.
8. Have the operator and technicians wash their hands with soap and warm water and don disposable gloves.
9. Have the operator remove the hair from a region ~15 cm x 15 cm around the biopsy site (via clippers). Note: clipping the hair from the biopsy site prevents hair from getting into the incision during the procedure and during closing, and hair removal allows for better contact between the tape closures and the skin (see 3.4).
10. Have the operator sterilize the area with swabs pre-soaked with a topical antiseptic, (such as povidone-iodine or chlorhexidine gluconate for subjects allergic to iodine/shellfish). Begin in the center and work in concentric circles towards the outer edge of the clipped area. At a minimum, repeat twice more with a new pre-soaked swab each time.

2. Biopsy Procedure

1. Have the operator remove disposable gloves, wash hands with soap and warm water, and don sterile surgical gloves using aseptic technique.
2. Have technician #1 present the sterile fenestrated drape to the operator. Have the operator, using aseptic technique, place the drape over the biopsy site to maintain a sterile field.
3. Have technician #1 present the operator a 5 ml syringe fitted with a 21 G needle while maintaining aseptic technique. Clean the top of the lidocaine vial with an alcohol swab.
    1. Have the operator immediately withdraw 5 ml of lidocaine. Remove the 21 G needle from the syringe and discard the needle into a sharps container.
    2. Have technician #1 present the operator with a 1-½ inch 25 G needle while maintaining aseptic technique. Have the operator place the 1-½ inch needle onto the syringe and evacuate the air bubbles from the syringe.
4. Have technician #1 spray ethyl chloride on the incision site (~0.5 cm above the indelible ink mark on the skin) until the skin appears to "blanch."
    1. Have the operator insert the needle approximately horizontal to the skin into the dermis, aspirate the needle, and then infiltrate with ~100 µl of lidocaine to produce a "bleb" 2-4 mm in diameter.
        1. Have the operator aspirate the needle (slightly withdraw the plunger of the syringe) to confirm that the needle has not been placed in a blood vessel. If blood appears in the syringe, withdraw the needle, discard in a sharps container, and begin again at 2.3.
        2. Have the operator advance the needle into the subcutaneous tissue, aspirate the needle, and then infiltrate the tissue with ~1 ml of lidocaine to form a bleb. Once the bleb has subsided, insert the 1-½ inch needle on the lidocaine-loaded syringe vertically into the incision site, stopping superficial to the fascia. Note: The subject may feel a slight momentary stinging sensation upon the initial injection of lidocaine (similar to a bee sting).
    2. Ensure that the operator does not infiltrate the muscle with lidocoine because it is myotoxic[17-19].
    3. Have the operator aspirate the needle and then slowly inject the remaining 4 ml of lidocaine while withdrawing the needle from the thigh. Place sterile gauze over injection site and allow the subject to relax while the local anesthetic takes effect.
5. After 2-3 min, have technician #1 present the operator a scalpel while maintaining aseptic technique.
    1. Have the operator lightly probe the biopsy site with the tip of the scalpel to confirm that the area is anesthetized. If necessary, inject another 3-4 ml of lidocaine into the incision site, see 2.4.1.2.
6. Have the operator make a straight 1-cm incision through the skin and subcutaneous tissues (~2-3 mm above the ink mark) parallel to the femur.
    1. Have the operator insert the scalpel deeper to make an incision through the fascia into the muscle. Do this once in each direction. Note: The subject may feel a twinge or pressure with the deeper cut if the scalpel blade cuts into the muscle.
    2. Have technician #2 engage the subject in conversation and massage the opposite leg.

7. Have the operator place a liberal amount of sterile gauze over the incision and biopsy site and apply direct pressure to the incision to reduce bleeding.
    1. Have technician #1 connect the 3-way metal stopcock to the disposable 60 ml syringe and the 30 cm extension tubing (**Figure 1**).
    2. Have technician #1 connect one end of the tapered plastic tubing connecter into the free end of the extension tubing and firmly insert the other end of the tapered plastic tubing connecter into the large end of a 200 µl pipette tip with ~15-18 mm of the tip cut off.

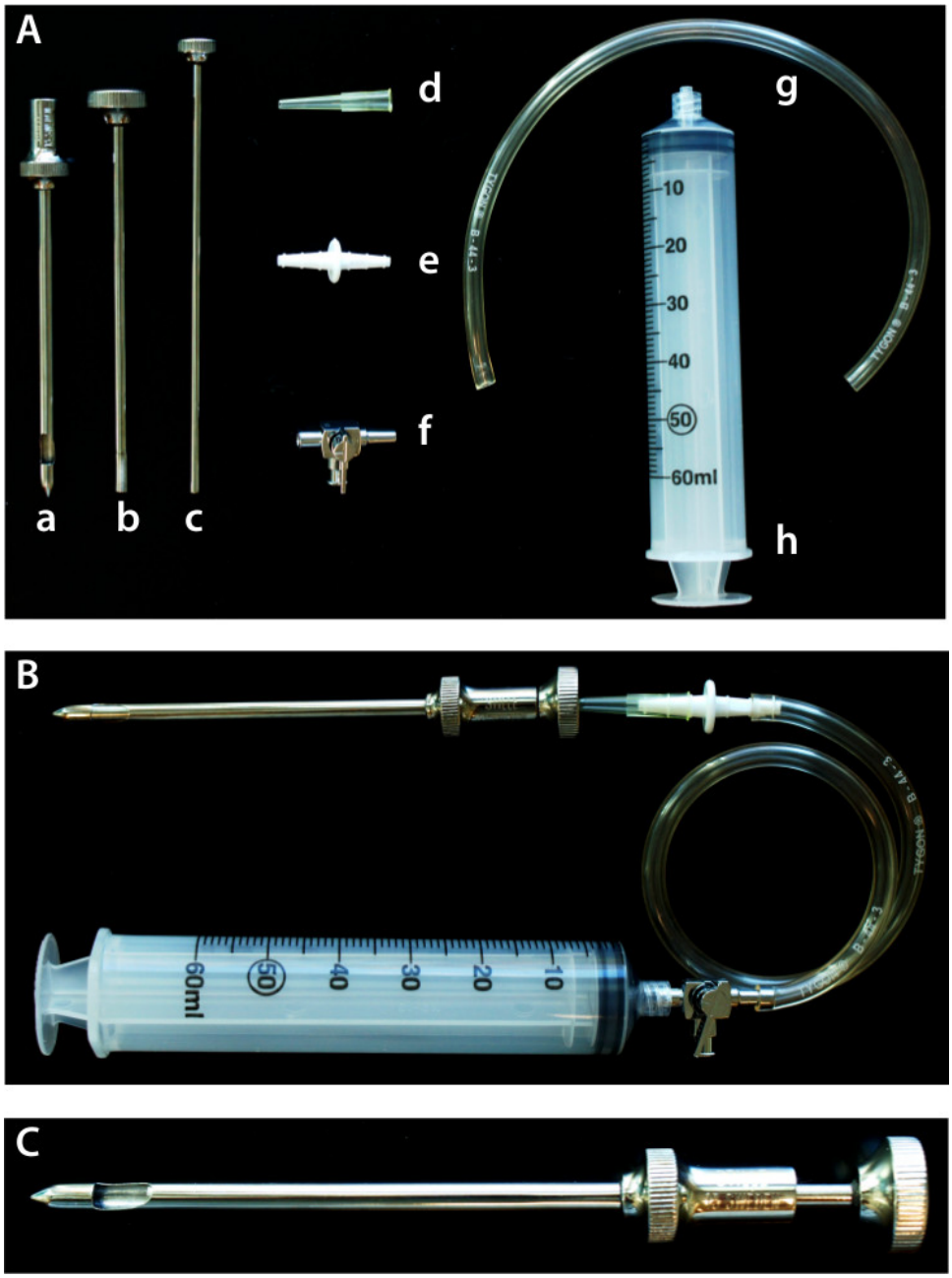

Figure 1. The Bergström needle. (A) The Bergström needle (5 mm) is composed of the (a) outer cannula and (b) inner trocar, the associated components include (c) plunger, (d) 200 µl pipette tip with ~15-18 mm cut off, (e) tapered plastic connector, (f) 3-way metal stopcock, (g) 30 cm extension tubing, and (h) disposable 60 ml syringe. **(B)** The Bergström needle (5 mm) and associated components assembled. **(C)** The inner trocar of the Bergström needle (5 mm) withdrawn approximately 1 cm opens the window of the outer cannula.

9. After the bleeding has subsided, have technician #1 open the sterilized autoclave pouch and present the 5 mm biopsy needle and inner trocar (**Figure 1**) to the operator while maintaining aseptic technique.
    1. Have the operator assemble the needle (outer cannula and inner trocar), check alignment and sliding action.

10. Have the operator firmly hold the needle assembly (outer cannula and inner trocar) with both hands to prevent the inner trocar from rotating. Have technician #1 firmly insert the cut pipette tip into the top of the inner trocar portion of the biopsy needle with a slight downward twisting motion. Ensure that technician #1 does not touch the operator or the biopsy needle, only the pipette tip.

11. Have the operator introduce the biopsy needle into the tissue through the incision. Locate the incision in the fascia (an acquired "feel") with the tip of the biopsy needle. Advance the needle just past the fascia and then angle the needle downward toward the floor as the needle is advanced into the muscle. Note: Subjects may experience some mild discomfort (*e.g.*, "deep pressure," or mild cramping sensation) as the incision through the fascia is located with the tip of the biopsy needle and the needle is advanced into the muscle.
    1. Have technician #2 instruct the subject to stay "relaxed" and not to contract their thigh muscles while the operator is advancing the needle into the muscle.

12. Once the biopsy needle is in position, have the operator signal technician #1 to open the disposable 60 ml syringe.
    1. Have technician #1 rapidly pull the disposable 60 ml syringe open to the 40-50 cc mark to create suction within the biopsy needle.
    2. Have the operator pull the inner trocar out approximately 1 cm to open the window of the outer cannula while maintaining the position of the outer trocar within the muscle. Have the operator rapidly close the inner trocar to cut (clip) and collect the muscle sample. Have the operator signal technician #1 to release suction.
    3. Have technician #1 open the stopcock to the room to release the suction.
    4. Have the operator rotate the biopsy needle 90° and repeat the process. If required, have the operator repeat the rotation procedure up to 3x (for a total of 4 clips).

13. Have the operator apply direct counter-pressure to the incision site with sterile gauze while removing the biopsy needle from the thigh, being careful not to catch fascia or skin. If significant resistance is felt, re-cut while applying a twisting motion to the inner trocar.
14. Upon removal of the biopsy needle from the thigh, have the operator pull the inner trocar back 1 cm to visually inspect the lumen of the outer cannula to estimate if an adequate amount of tissue was collected.
    1. Have the operator hand the biopsy needle to technician #1. To maintain aseptic technique ensure that technician #1 only touches the needle, not the operator. Have technician #1 hand the biopsy needle to technician #3.

15. Have technician #3 remove the tissue from the biopsy needle.
    1. Have technician #3 use the plunger (**Figure 1**) and a pair of fine tip forceps to ensure that all muscle tissue is removed from the inner trocar and outer cannula.
    2. Have technician #3 quickly weigh the sample to confirm that an adequate amount of muscle tissue was collected and place the samples on an ice-cold dissection block.

16. Have technician #3 carefully dissect visible connective tissue and fat from the muscle samples. Have technician #3 prepare the muscle samples for storage according to downstream analyses. For example, immediately place samples in a cryovial and snap freeze in liquid nitrogen, mount and freeze for histology, or place in a cryovial with RNase inhibitor, etc.
17. If necessary, repeat the procedure with a second sterilized biopsy needle while maintaining aseptic technique.

3. Closure

1. Have the operator apply direct pressure to biopsy site with sterile gauze and an ice pack for 10-15 min.
2. Once hemostasis is achieved, have the operator use alcohol prep pads to remove dried blood from the area around the incision.
3. Have technician #1 present a tube of topical surgical adhesive and applicator to the operator. Have the operator assemble the tube of surgical adhesive and applicator without touching the applicator tip or the top of the tube.
4. Have the operator pull the incision closed with one hand while applying a single layer of surgical adhesive over the top of the dry incision with the other hand. After the adhesive cures (~ 90 sec), apply tape closuresperpendicular to the incision. Alternatively, close the incision with two sterile 4-0 sutures.
5. Have the operator apply direct pressure by placing 3-4 2" x 2" non-sterile gauze pads on the incision site and secure with self-adhering adhesive wrap.
6. Have the operator provide the subject verbal and written instructions on proper wound care, normal and abnormal reactions, and activity guidelines for the following 1 to 4 days (see online supplement 2).

Representative Results

The muscle biopsy procedure as described above allows the researcher to quickly and consistently collect skeletal muscle tissue samples. The typical yield in healthy, athletic subjects is 200 mg or more in a single pass with 3-4 clips. The procedure takes 15-20 min, most of which is spent in preparation for the incision. In exercise-based studies, muscle samples are often taken pre- and post-exercise, with one or two samples collected during recovery. With this design, the hair on the post-exercise (contralateral) thigh is clipped and the incision site is pre-marked with a fine point permanent marker while the pre-exercise thigh is being prepared for the procedure. Doing so allows the muscle biopsy to be taken in 8-10 min during[20] or after a bout of prolonged exercise. Alternatively, when investigating shorter periods of exercise (*e.g.*, 30 min or less) an incision(s) can be made prior to exercise, covered with sterile dressing and fastened with surgical tape, thus, allowing the biopsy sample to be taken rapidly (10 sec[21] to 4 min[22]) after completing a bout of exercise. The relative quickness of the procedure enables the researcher to capture cellular and molecular events before, during, and after a bout of exercise, and to test the interaction effect of a nutritional intervention.

The ASU Human Performance Laboratory has published several sports nutrition based papers utilizing data from muscle tissue biopsy samples. Important scientific discoveries made from the ASU research group include:

Gene expression of IL-1β, IL-6, IL-8, and TNF-α is increased in skeletal muscle tissue obtained from experienced endurance athletes after 3 hr of running. Carbohydrate intake (60 grams/hr) attenuated IL-6 and IL-8 mRNA levels despite having no effect on skeletal muscle glycogen depletion[8] (**Figure 2**).

A 2-hr intensive resistance training bout increased muscle tissue cytokine mRNA for IL-1β, IL-6, IL-8, and TNF-α in 30 experienced weight lifters (i.e., same cytokines as elevated following running). The increases in muscle tissue mRNA expression were large but without corresponding increases in plasma cytokine levels. Carbohydrate intake did not influence the pattern of change in muscle tissue cytokine mRNA expression[9].

Carbohydrate ingestion by 15 trained cyclists attenuated plasma IL-6 compared to placebo, but had no influence on muscle tissue glycogen depletion or IL-6, IL-8, TNF-α mRNA expression following 2.5 hr of cycling[11].

Quercetin (1,000 mg/day for 3 weeks) ingestion by 40 trained cyclists did not alter exercise-induced increases in muscle tissue NF-κB, COX-2, IL-1β, IL-6, IL-8, or TNF-α mRNA expression compared with placebo[15].

In contrast to what was found in mice[23], 1,000 mg/day quercetin for 2 weeks had modest, but insignificant, effects on markers of mitochondrial biogenesis in 26 untrained human subjects[13].

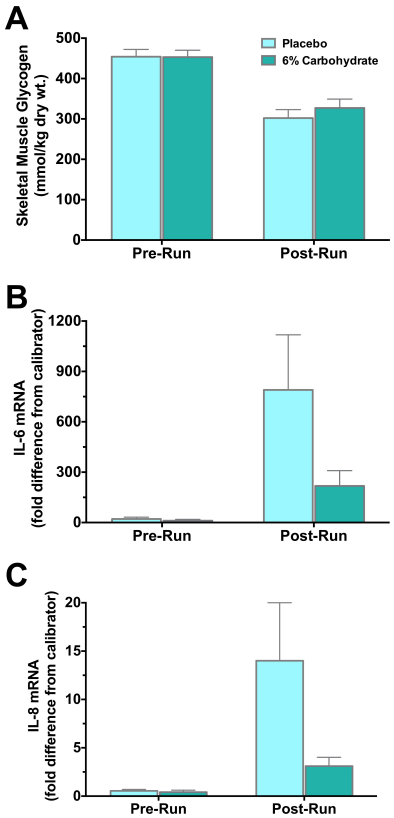

Figure 2. Data obtained from human skeletal muscle tissue biopsies. In a randomized, placebo controlled, crossover study male endurance athletes (n = 16) ran on treadmills for 3 hr at 70% VO_{2max} and consumed a 6% carbohydrate beverage or a placebo beverage at a rate of 1 L/hr[8]. Skeletal muscle tissue biopsies were taken pre- and post-exercise, immediately placed on an ice-cold dissection block, and visible connective tissue and fat was carefully removed. The biopsy sample was then placed in a cryovial, frozen in liquid nitrogen, and stored at -80 °C until analysis. **(A)** Carbohydrate ingestion did not influence skeletal muscle glycogen depletion (p = 0.246, interaction effect). However, carbohydrate ingestion tended to attenuate the increase in **(B)** skeletal muscle tissue interleukin (IL)-6 mRNA levels, and **(C)** skeletal muscle tissue IL-8 mRNA levels (p = 0.071 and p = 0.063, interaction effect, respectively)[8].

Item	Quantity per biopsy
Gloves, non-sterile	3
Durasorb blue pad	2
Face mask	1
Prep razor, disposable	1
Shave cream	partial can
Permanent marker / indelible marker	reusable
Betadine Swabsticks (3 pack)	1
Sterile surgical gloves (size dependent)	1
Fenestrated towel drape	1
Ethyl chloride spray	0.1
Lidocaine (1% w/o Epi)	5 cc
5 ml syringe w/ 21 G needle	1
25 G 5/8" needle	1
25 G 1 1/2" needle	1
Single-use scalpels w/ #11 blade	1
Sterile 4 x 4 gauze pads	4
Packaged sterilized Bergström biopsy needle	1
60 ml Syringe	1
Extension tubing	~75 cm
Metal stopcock	1
Plastic connector	1
Cut yellow (1-200 µl) pipette tip	1
Alcohol swabs	5-10
Octylseal, liquid sutures	1
Steri-strip 1/2" x 4"	1
Bandage	1
Non-sterile 2 x 2 (or 4 x 4) gauze pads	2 (or 1)
Adhesive bandage (5 m roll)	0.25
Paper tape to secure adhesive bandage	~30 cm

Table 1. Muscle Biopsy Materials List.

Discussion

This video provides a step-by-step summary of the skeletal muscle biopsy procedure used at the ASU Human Performance Laboratory. This procedure, with small modifications, has been used to collect approximately 1,600 muscle biopsies during the past 13 years. The muscle biopsy samples have provided important data in sports nutrition based investigations, leading to important research discoveries.

There are many critical techniques to be aware of when performing the modified Bergström skeletal muscle biopsy technique. First and foremost, the biopsy team must maintain strict aseptic technique during all phases of the procedure. When locating the incision site [1.4] it is important to note that the vastus lateralis, when contracted, is more anterior and proximal than would be in the relaxed state during the biopsy. If the study procedures require additional biopsies from the same thigh, the initial incision site should be slightly distal of the one-third point [1.4]; each subsequent biopsy is 2-3 cm proximal to the preceding one. The gauging the approximate skinfold thickness [1.6] aids the operator to estimate the amount of tissue superficial to the fascia, an important determination for steps 2.3.2, 2.4.1, 2.6, 2.6.1, and 2.11.The operator must learn to sense the change in resistance between the subcutaneous tissue and the fascia [2.4.1]. When administering local anesthetic, this sense will assure the quality of the muscle biopsy by enabling the operator to adequately infiltrate the subcutaneous tissue while minimizing direct exposure of the skeletal muscle tissue to myotoxic[17-19] local anesthetic [2.4.2]. When cutting through the subcutaneous tissue, a sense of this change in resistance will provide the operator with an indication of the depth of the fascia [2.6]. The operator should make a mental note of how deep the scalpel is relative to the skin and the relative position of the incision in fascia [2.6.1]. This will decrease the amount of time spent by the operator probing for the fascial incision and assist the operator in determining whether the window of the biopsy needle is completely in the muscle. The entire window of the outer cannula (**Figure 1**) must be within the muscle fascia. With very lean subjects this is easily confirmed

by visual inspection, however, this is more difficult to ensure in subjects with considerable subcutaneous tissue. Technician #1 must learn to gauge the degree of suction applied when the syringe is pulled open [2.12.1]. Low suction could indicate a weak union at the pipette tip-biopsy needle junction or incomplete penetration of the biopsy needle into the muscle. Both scenarios increase the likelihood that a repeat biopsy will be necessary to achieve an adequate amount of muscle tissue. With experience, technician #1 should also estimate the amount of tissue clipped based on the degree of resistance felt when suction is being applied. This information should be relayed to the operator. Similarly, the operator can estimate the amount of tissue clipped based on the "feel" of the cut made when closing the inner trocar [2.12.2]. The operator must rapidly clip the muscle after technician #1 creates suction with the syringe [2.12.2]. Clipping the muscle tissue at the point of maximal suction will improve tissue yield. The method of multiple clips with a single pass of the biopsy needle helps to ensure that a sufficient amount of tissue is obtained for the study and minimizes subject discomfort by decreasing the number of times the biopsy needle is inserted into the muscle through the fascial incision [2.12.4]. The operator should remove the biopsy needle from the incision with a slow, twisting motion while using their free hand to apply counter pressure with sterile gauze [2.13]. This will help prevent the window of the biopsy needle from getting "hung up" on the fascial and dermal incisions. A feeling of resistance while withdrawing the needle may indicate an incomplete cut through the muscle. If an incomplete cut is suspected, the operator should stop removing the biopsy needle and recut the remaining fibers by opening the inner trocar 4-5 mm and apply a slight twisting motion as the inner trocar is closed. Finally, after removing the biopsy needle, apply a cold compress to the incision site for 10-15 min, some subjects may require a longer time period to achieve hemostasis [3.1]. After hemostasis has been achieved, carefully clean the area around the incision with alcohol prep pads, and let the skin dry before applying the surgical adhesive [3.2-3.4]. These techniques will maximize the benefits of using surgical adhesive to close the dermal incision and the effectiveness of the adhesive bandages to stick to the skin. The surgical adhesive has several advantages over tape closures and sutures. Subjects can exercise vigorously for hours immediately after the procedure without bleeding from the incision. The surgical adhesive provides a physical barrier against potential infection, does not require removal, and minimizes scarring.

The muscle biopsy procedure is minimally invasive, relatively safe, and may be performed in biomedical research settings as an outpatient procedure. Most subjects report little change in their ability to conduct normal daily activities of living. Soreness and swelling from the procedure is fully resolved within 5 to 7 days. Few adverse events have been reported from subjects involved in studies conducted at the ASU Human Performance Laboratory (approximately 2 out of 1,600, both were local skin infections). This incidence rate is similar to other published reports. Bergström reported[3] a very low incidence of intramuscular haematomas, which resorbed spontaneously, and only one case out of more than 5,000 biopsies requiring surgical intervention to stop arterial bleeding. Hennessey *et al.*, using a suction modified Bergström technique, reported that 2 biopsies out of 83 resulted in a disruption of the subject's daily activities due to pain and discomfort. One of these events was due to an ecchymosis, and both events resolved within 7 days[6]. Tarnopolsky *et al*. report a very low complication rate with the suction modified Bergström technique (22 complications out of 13,914 biopsies in adults and children[7]). Complications included local skin infection (8 cases), arterial bleed (2 cases), ecchymosis/hematoma (2 cases), pain persisting for > 3 days (5 cases), and a small area local numbness distal to the biopsy (5 cases)[7].

The modified Bergström muscle biopsy technique elevates the quality of data collected during a study while imposing minimal time constraints. The procedure can be completed rapidly when the incision site is prepared ahead of time, a single pass of 3-4 clips typically yields 100 to 200 mg of tissue, and multiple biopsies can be taken from a subject during a single session. Muscle samples collected with this technique can be used for a broad array of outcome measures, including fiber typing, muscle damage, fuel substrate stores, mitochondrial biogenesis and respiration, enzyme activity, shifts in metabolites, protein synthesis, gene expression for inflammation and oxidative stress, and numerous others.

Obtaining the muscle biopsy sample from the vastus lateralis offers advantages over other candidate muscles (e.g., the biceps brachii, deltoid, gastrocnemius, tibialis anterior, triceps brachii, and soleus muscles). The vastus lateralis is the most commonly sampled muscle, and an extensive amount of normative histological, biochemical, and molecular biology data exist for the researcher and clinician to compare their findings and observations. Secondly, the area of the vastus lateralis where the incisions are made is relatively large and does not have major blood vessels or nerves overlaying the area. Thus, during a given test session multiple incisions in the same muscle should be made, each 2-3 cm apart, to prevent trauma-induced changes in gene expression[24]. Obtaining multiple biopsies from the same muscle through separate incisions does not apparently alter the transcriptional response of genes responsive to the stress of exercise[24,25]. However, the expression of certain genes may be influenced when a second biopsy is taken through the same incision several hours later[24]. Finally, subjects are able to engage in 2-3 hours of exercise with little discomfort when the muscle biopsy is obtained from the vastus lateralis. Many subjects compare the post-biopsy discomfort to a mild contusion. This allows for pre- to post-exercise samples to be obtained with little subject burden[3,8,11,26].

In summary, a method for extracting human skeletal muscle biopsy samples using the modified Bergström technique was described. This muscle biopsy procedure is relatively safe and provides the researcher with ample skeletal muscle tissue for multiple downstream cellular and molecular assays. The procedure can be completed quickly, allowing the researcher to obtain pre-, mid-, and post-exercise (or other intervention) biopsy samples.

Disclosures

The authors have no conflicts of interest.

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