ORIGINAL ARTICLES

Noninvasive Laboratory Exercise Demonstrating Blood Pressure Response to Isometric or Straining Forms of Exercise

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A simple method of demonstrating blood pressure changes during isometric or straining forms of exercise in a teaching laboratory is valuable. Techniques involving cannulation of an artery require patient consent and are time consuming. The present paper describes a technique that uses a Biopac MP30 data acquisition unit, Biopac Student Lab *PRO* software, and modified sphygmomanometer to determine and analyze systolic and diastolic blood pressures during an isometric contraction; resistance is produced via a modified hydraulic leg press. This method is safe, noninvasive, easily calibrated, and provides a rapid measurement and analysis of the data. (The Journal of Chiropractic Education 14(2): 63–67, 2000)

Key words: blood pressure determination, blood pressure monitors, exercise test, laboratory techniques and procedures

INTRODUCTION

Rhythmic, steady-rate, muscular activity such as jogging, swimming, or cycling causes metabolic vasodilatation in the working muscles. Dilation of the blood vessels in the active muscles decreases total peripheral resistance, increases venous return (preload), and increases cardiac output. In addition, during the first few minutes of the exercise, the increased blood flow produces an initial rise in systolic pressure. As the arterioles continue to dilate in the exercised muscles, peripheral resistance to blood flow decreases with a possible accompanying reduction in systolic pressure. The diastolic pressure remains relatively unchanged during these forms of exercise.

Isometric (static) contractions or straining forms of exercise, such as exhibited during weight training, evoke a different cardiovascular response (1). These forms of contractions are characterized by increased vascular resistance within the exercised muscles. The concentric phase of the muscle action compresses the peripheral arterial system with a concurrent increase in cardiac afterload and a decrease in venous return. This, in turn, results in an increase in both systolic and diastolic blood pressures. Blood pressure readings as high as 320/250 have been elicited during heavy squats (2). Additional increases in blood pressure may be seen during a heavy resistance lift and a Valsalva maneuver—elevations as high as 480/350 in highly trained individuals have been reported (2).

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OBJECTIVES

The auscultatory method is most commonly used to determine blood pressure. In a teaching situation, however, the beginning student often has great deal of difficulty hearing the Korotkoff sounds. This problem is compounded when the student attempts to determine blood pressure during exercise. The objectives of this physiology lab procedure are to demonstrate and evaluate systolic and diastolic pressure changes during voluntary isometric contractions, and to identify and correlate the appearance and the

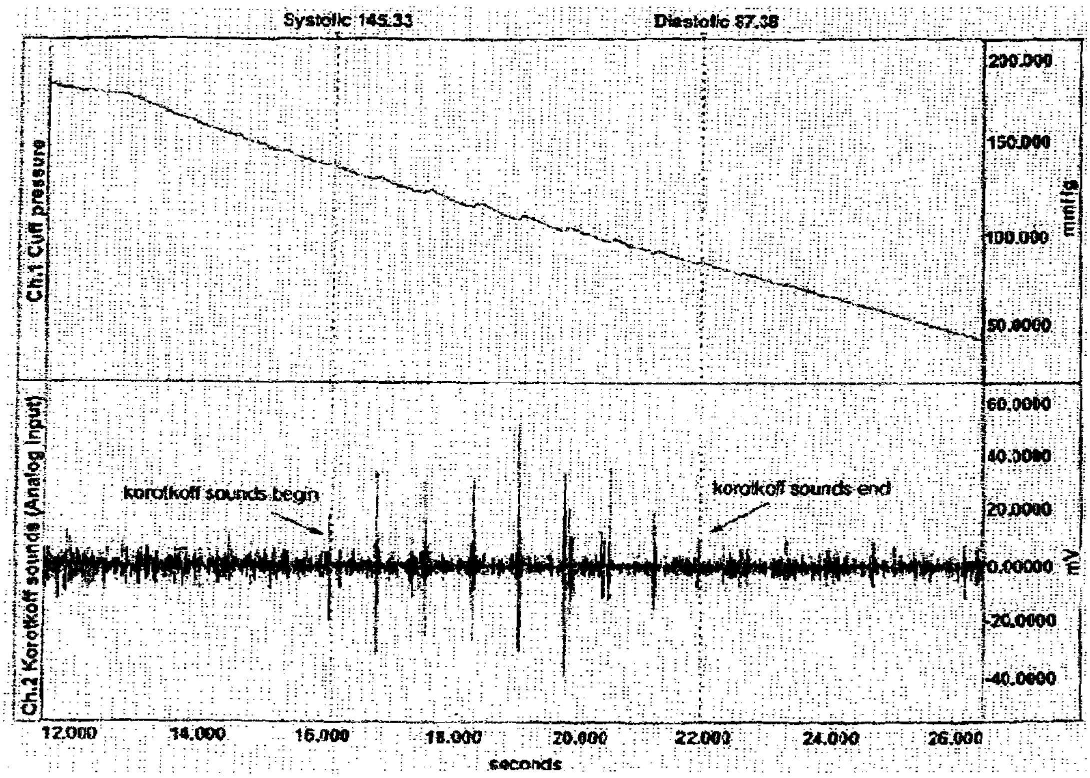

Figure 1. Resting blood pressure, Ch. 1 displays the inflation and deflation pressures, in mm Hg, of the blood pressure cuff. Ch. 2 indicates the appearance and the cessation of the Korotkoff sounds.

cessation of the Korotkoff sounds to the isometric load.

MATERIALS AND METHODS

The procedure described is presently part of a physiology lab at Parker College of Chiropractic, and requires the following equipment:

- PC with Windows
- Biopac MP30 data acquisition unit
- Biopac Student Lab *PRO* software
- Biopac piezoelectric ceramic microphone (SS17L)
- Blood pressure cuff and Biopac pressure transducer (SS19L)
- Hydraulic leg press and pressure transducer

There are three sources of the data collected and displayed:

- Cuff pressure (Ch. 1)—All pressure changes in the blood pressure cuff are recorded via a cuff pressure signal transducer.
- Korotkoff sounds (Ch. 2)—Ordinarily, the Korotkoff signal is detected by means of a piezoelectric ceramic microphone attached to the inside of the blood pressure cuff with Velcro. The blood pressure cuff is positioned so as to place the ceramic microphone directly over the brachial artery.
- Force generated during an isometric contraction (Ch. 3)—The force generated by the subject using the hydraulic leg press is detected via a pressure transducer attached to the hydraulic cylinder.

The Biopac MP30 data acquisition unit and the Biopac Student Lab *PRO* software is used to collect, display, and analyze all data. Prior to the start of data acquisition, the blood pressure cuff transducer (SS19L) and the hydraulic leg press transducer are calibrated according to manufacturer's instructions.

As the subject sits on a stool quietly, all of the appropriate sensors are attached. From this position, the resting blood pressure values are determined and recorded from the data displayed on the monitor (Fig. 1). Ch. 3 will not exhibit an isometric force value at this point.

The variable orifice (Fig. 2) of the hydraulic cylinder on the leg press unit is opened next, and the subject is positioned carefully under the shoulder pads. The subject is instructed to bend the knees approximately 120°; this position allows the exertion of a continuous, steady isometric force. The

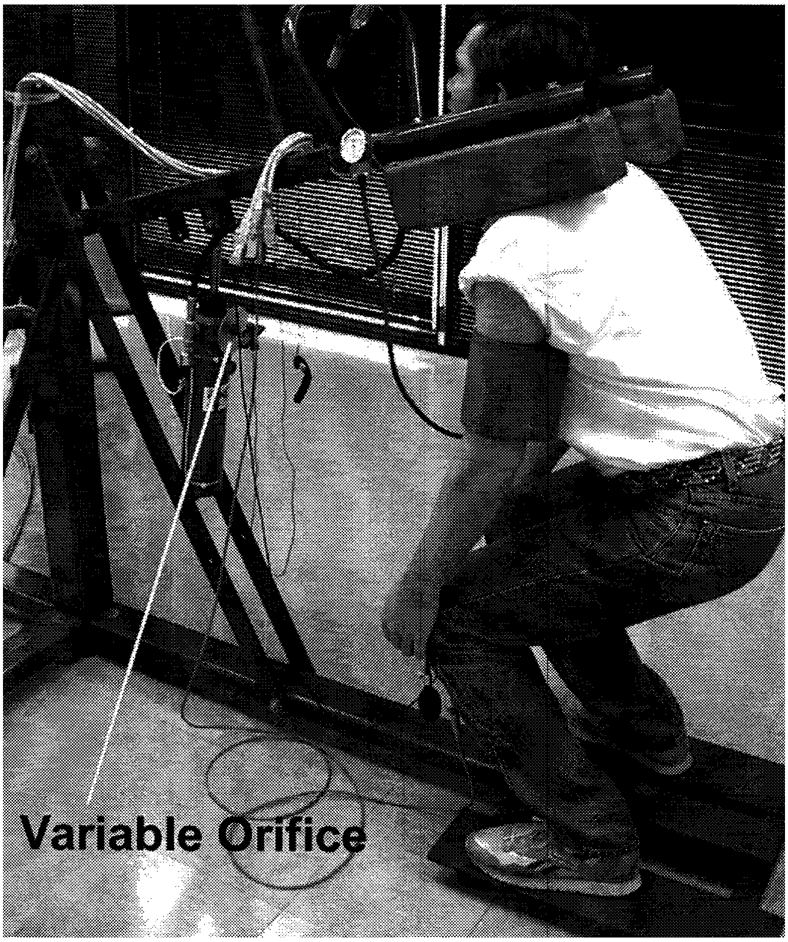

Figure 2. Hydraulic leg press used to generate a predetermined sustained isometric contraction.

variable orifice is then closed. When this setup has been completed, the MP30 data acquisition unit is "clicked on," and the subject is signaled to produce and sustain a predetermined isometric contraction (in pounds of force generated). The force exerted by the subject is monitored via the hydraulic pressure gauge. After 5–10 seconds of exerting the predetermined force, the blood pressure cuff is inflated quickly and then allowed to deflate rapidly and smoothly. The subject is instructed to relax as soon as the blood pressure determination has been completed. The data are once again displayed on the monitor, where they can be analyzed and then printed (Fig. 3). The data collected are quickly and easily analyzed with the use of postacquisition analysis functions and transformations of the Biopac Student Lab *PRO* software.

Table 1 gives several examples of resting blood pressure and the change in blood pressure as a result of an isometric contraction. All examples were obtained using students as subjects.

DISCUSSION

Simple, effective, and hands-on demonstrations of physiological phenomena have always been a challenge in a teaching lab. This is especially true with the current decline, and in some cases total elimination, of the use of live animal models. Invasive procedures to demonstrate physiological responses to various insults on human volunteers are also difficult. In the case of arterial blood pressure response to isometric or straining forms of exercises, local anesthesia and brachial artery cannulation are required. In addition, the pressure transducer and the system utilized may require elaborate calibration. Procedures such as these are time consuming, and, in accordance with the institution's ethics committee, require an informed consent, to the associated risks from the volunteer. The blood pressure determination described in this lab exercise is noninvasive, can be quickly calibrated, and yields reproducible results.

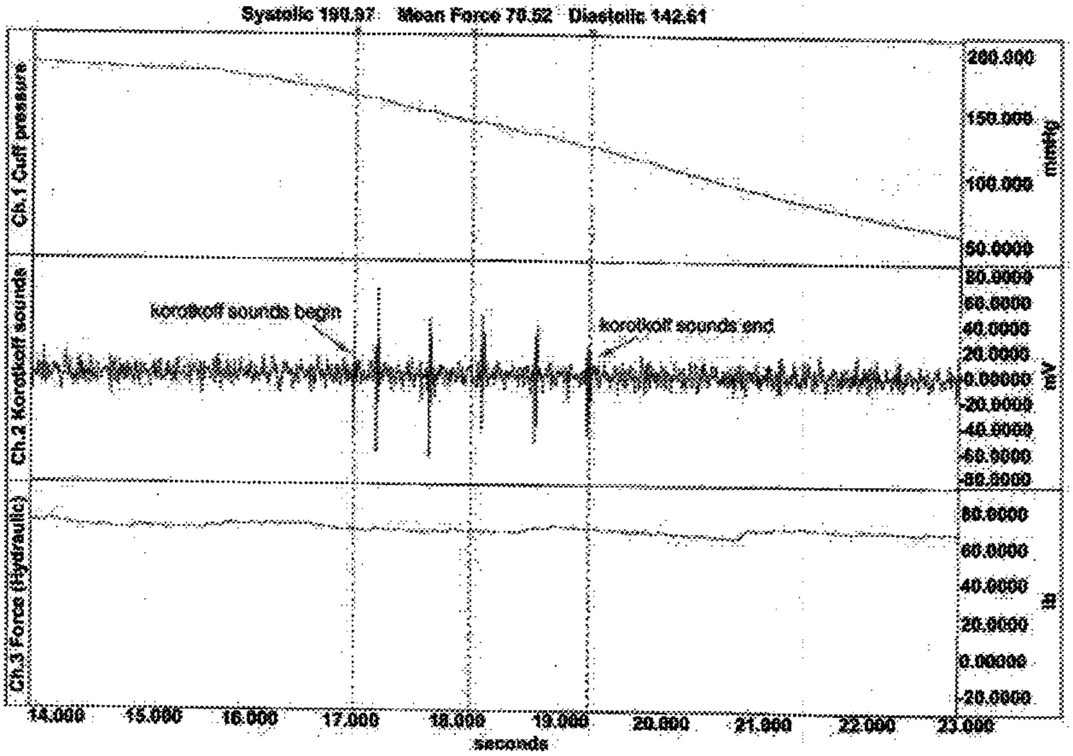

Figure 3. Isometric blood pressure (piezoelectric microphone below blood pressure cuff). Ch. 1 displays the inflation and deflation pressures, in mm Hg, of the blood pressure cuff. Ch. 2 indicates the appearance and the cessation of the Korotkoff sounds. Ch. 3 shows the force, in pounds generated by the subject during an isometric contraction.

Table 1. Blood Pressure Response to an Isometric Contraction

Subject	Resting blood pressure	Isometric blood pressure	Mean force (lb)
1	127/76	167/77	122
2	145/87	191/142	71
3	128/64	174/117	121
4	127/58	145/79	70
5	100/54	120/61	44
6	115/57	133/73	109
7	109/52	157/81	128

An accurate visual display of the Korotkoff sounds during straining type of exercises requires careful attention to certain components of this lab exercise. One of these is the correct bladder length in the blood pressure cuff. The bladder length should encircle the subject's arm; a bladder that is short may not properly compress the brachial artery and thus result in falsely high readings. An "obese" size bladder (15 × 31 cm) or a "thigh" sized bladder (18 × 36–50 cm) should be used on individuals with obese or excessively muscular arms.

Another essential element of this lab exercise is the correct placement of the piezoelectric ceramic microphone, which must be placed directly over the brachial artery. This may prove to be a challenge in the case of an obese arm. Additionally, even if the microphone is positioned correctly, the thicker subcutaneous fat layer may interfere with the detection of clean Korotkoff sounds. Difficulty in the detection of the Korotkoff sounds may also be encountered if the arm contains heavy musculature (i.e., body builders). The brachial artery is slightly overlapped in the upper half of the upper arm by the coraco-brachialis and in the lower half by the biceps brachii. Hypertrophy of the biceps brachii may result in a deeper medial bicipital furrow, which in turn could impede the proper positioning of the piezoelectric device against the brachial artery. Ideally, the arm should be of average musculature with less than the average amount of subcutaneous adipose tissue.

If placement of the blood pressure cuff below the piezoelectric microphone fails to generate acceptable Korotkoff signals, an alternate placement of the microphone can be tried. The microphone is positioned separately over the brachial artery in the antecubital fossa and is held in place by a Velcro strap that is not part of the blood pressure cuff.

The generation of a clean Korotkoff sound display requires that the isometric force be created only with the legs; the arms must be totally relaxed. Any involvement of the arms during the straining contraction produces rubbing on the microphone, which in turn will be displayed as substantial background noise. This rubbing makes it very difficult to extract the points where the Korotkoff sounds identify the systolic and diastolic pressures. The problem is exacerbated if the subject is not familiar with weightlifting techniques or is simply trying to generate an extremely high isometric force. Maximal voluntary muscular contractions are not required to observe blood pressure changes in this laboratory exercise. A sustained contraction of approximately 20% of a maximal voluntary contraction will induce a rapid increase in both systolic and diastolic blood pressure, and will produce an optimal display of the Korotkoff sounds.

Lastly, the procedure could also be used as a platform to demonstrate physiological responses to other extraneous variables. Examples include:

- Isometric blood pressure response in young versus elderly subjects
- Isometric blood pressure response in male versus female subjects
- Isometric blood pressure response induced by upper body contractions versus lower body contractions
- The effect of food ingestion on blood pressure
- The effect of caffeine ingestion on blood pressure
- The effect of cigarette smoking on blood pressure
- The effect of a full urinary bladder on blood pressure
- The effect of postural changes on blood pressure

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