NSU Florida
NOVA SOUTHEASTERN UNIVERSITY

NeuroSports

Volume 1 Article 4

2020

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Cover Page Footnote

This work was not supported by any grant funding. The authors have no financial interests to disclose. We acknowledge the continued support of the Athletes, Coaches and Patients.

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CONFIDENTIAL DRAFT Journal of NeuroSports Revision. GALLEY

Under review for NeuroSports – not redacted version.

An objective method to assess and recommend exertion and exercise targets for return to play post-concussion.

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Running title: Concussion and Exertion Assessment.

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Abstract. (360 words)

Introduction

Concussions are of significant concern for athletic trainers, and there is a critical need to objectively and safely allow an athlete to return to play. In sports the objective is return as safely and soon as possible. Exertion is a consideration regarding progressing an athlete back to play. The ability to exert in cardiovascular and strength and conditioning contexts are two critical steps in most return to play protocols. Being able to make objective recommendations is urgently needed, as trial and error leads to unnecessary risk of eliciting symptoms and/or causing setbacks.

Objective

The object of this paper is to present the athletic trainer with data associated with a methodology that can be used to aid in designing a cardiovascular and strength training program post-concussion. This objective measure does not rely on subjective patient reports of symptoms and utilizes a reflex-based assessment method.

Description

The transient exertion related carotid (TERC) murmur is a murmur that is heard at the carotid arteries during exercise. It normally is heard at around a heart rate of 150 but is heard at lower heart rates in patients who have sustained a concussion. Listening for the TERC murmur during a cardiovascular and strength training assessment can be used to provide information to the athletic trainer about safer target heart rates or safer lifting strategies post-concussion. We present data concerning 71 athletes who were assessed for cardiovascular conditioning and body weight

assessment. With 73% of the cardio assessment subjects, a TERC murmur was detected at a heart rate of (M = 127.2, SD = 16) BPM. For the strength assessment 42.1% had a TERC murmur.

Clinical advantages

The clinical advantage of the TERC murmur is that it can be utilized by any athletic trainer trained to take a blood pressure. It provides objective information concerning safe target heart rates that will allow an athletic trainer to recommend appropriate exercise prescriptions. The TERC murmur assessment can also be used to help guide strength training protocols to facilitate safe return. Being able to safely recommend a means by which an athlete can recommence their training (cardiovascular and/or strength training) may accelerate return to play as well as aid in keeping the athlete happy, healthy and engaged.

Background

Objective

The objective of this paper is to present data and methods that can be used to determine exertion limits for cardiovascular and strength training based an objective TERC murmur instead of self-reported symptoms. This will allow the athletic trainer to assess and recommend a progression for cardiovascular and strength training for an athlete who sustained a mild traumatic brain injury (Mtbi). Concussion or Mtbi has become a substantial health burden in athletics and for athletic trainers (Dech et al., 2019, Evans 2018, Harmon et al., 2013). There are published methods to allow safe exertion as part of a return to play program (Haider et al., 2019, Leddy et al., 2019, Leddy et al., 2019b). The Buffalo Treadmill protocol is best suited for cardiovascular assessment and is dependent upon self-reported symptoms from the athlete. There is always a concern

regarding the subjectivity and competing interests of self-reported symptoms in athletics. An objective method for athletic trainers to promote decision making for cardiovascular and strength training is currently lacking (Ledoux et al., 2019, Makdissi et al., 2014). This paper employs the method of auscultation of the carotid TERC murmur (Clark et al 2016) to develop a target heart rate for both cardiovascular conditioning and strength training.

Athletic trainers and sports medicine practitioners know that athletes are prone to concealing symptoms post injury, in a somewhat misguided attempt to get back to play sooner (Delaney et al., 2015). According to Delaney et al., (2015) athletes report they are downplaying their concussion or concussion symptoms for two main reasons: they think it is not that bad or they want to get back to play. In either case, we are left with a need to employ objective measures to aid in guiding an athlete through rehabilitation post injury, including post-concussion (Clark et al., 2014, Dech et al., 2019).

There is a growing body of literature that suggests and supports the concept of exercise and exercise prescriptions being associated with better and faster outcomes post-concussion (Maerlender et al., 2015, Ledoux et al., 209, Leddy et al., 2019 a and b). While there are some papers that also point out that early exercise can lead to symptom exacerbation (Dematteo et al., 2015, Haider et al., 2019, Howell et al., 2020, Leddy et al., 2019 a and b, Ledoux et al, 2019, Miranda et al., 2018, Sawyer, et al., 2016, Davis et al., 2018), there is a growing consensus that safe and evidence-based progression of exercise will aid in recovery (Davis et al., 2018, Harmon et al., 2013). Sports medicine professionals are accelerating exercise post-concussion to aid in return to play and mitigate symptoms such as depression (Silverberg et al., 2013, Simon et al., 2009). A partial goal of this paper is for the athletes to safely return to training as soon as possible.

Following a concussion, most athletic trainers will have a staged return to play program (Davis et al., 2018, Harmon et al., 2013), which will include exertion at some stage. For the sports medical practitioner, exertion assessments are performed before return to exercise, return to sports and / or developing an exercise prescription. In this paper we use the term exertion as part of the assessment protocol and exercise as the goal for next steps in return to play. Questions remain as to when it is safe to start exertion and what is/are proper target heart rates (Clark et al., 2016, Haider et al., 2019, Leddy et al., 2018 and 2019). When the patient is cleared for cardiovascular exercises, does that mean strength training should be cleared without restrictions

(Evans 2018)? We believe there can be objective measures to allow safe return to training and these measures are presented below.

Bruit is a term used to describe an abnormal flow heard during auscultation. The noise heard is caused by turbulent blood flow (Ene–Iordache et al., 2017, Jahangiri et al., 2015, Kurtz 1990, Lucerna 2020). It has recently been reported that bruit, or the transient exertion related carotid murmur (TERC murmur), may be useful to assess cerebrovascular health post-concussion (Clark et al., 2016). The TERC murmur is a normal reflex that the brain uses to maintain constant and laminar flow into the brain's perfusion system. The laminar flow and dampened pulse pressure wave are thought to maintain nutrient and oxygen delivery to the brain tissues when the TERC murmur is heard. Turbulent flow decreases the efficacy of oxygen and nutrient exchange, so the brain strives to maintain laminar flow (Jahangiri et al., 2015, Kurtz 1990). The TERC murmur reflex appears at an average heart rate of 150 beats per minute (BPM) (Clark et al., 2016). Recently Clark et al., reported that the TERC murmur can be heard at a heart rate of about 120 BPM post-concussion (Clark et al., 2016).

The TERC murmur likely occurs at lower heart rates in the concussion patient because there may be friable perfusion beds or damaged regions of the brain that are sensitive to the pulse pressure wave caused by exertion. They then experience exertion related symptoms (Clark et al 2016, Dech et al., 2019, Sawyer et al., 2016, Miranda et al., 2018, Leddy et al., 2019, Evans 2018). In this case, the TERC murmur begins at relatively lower heart rates in the cerebral vascular system's attempt to protect the damaged regions of the brain. Vascular nociceptors may also be involved in the reflex. An in-depth analysis of the pathophysiology underlying the TERC murmur reflex is beyond the scope of this article. However, the ethos of this article is to use the TERC murmur reflex as a guide to aid in making clinical decisions and recommendations of exertion in the post-concussion patient. The TERC murmur reflex will be used to assess cardiovascular exertion (exercise bike) and serve as a segue to strength training.

Methods

We performed a retrospective analysis of patient visits that included an exertion assessment. Specifically, patients were included in the study if they were competitive high school, college or professional athletes that received a post-concussion diagnosis by one of the four team physicians from the University of Cincinnati health care system. Patients were excluded if there was a suspicion of cardiovascular deficiencies or contraindications to exertion based on medical history or self-reports. When clinically indicated and no contraindications, an exertion assessment was performed. Of the charts reviewed, the main exclusion criterion was an exertion assessment was not performed.

We used the same exercise bike at the lowest setting of resistance for all exertion tests.

As the exertion assessment is part of our clinical protocols there was no consent signed. This retrospective chart review was reviewed by the University of Cincinnati IRB.

TERC Murmur Methods

The following methods should be performed by experienced athletic trainers or health care providers, and the tests should be performed on patients who prior to a concussive injury would easily be able to do said exertion tests. Please make sure that the fitness of the athletes being tested are consistent with the demands of the tests. The athlete must be continuously monitored throughout.

The TERC murmur reflex assessment is performed using a standard stethoscope and measures the heart rate at the radial artery by palpation for 15 seconds. We perform the test on an incumbent bike. The bike produces less noise than a treadmill such that the TERC murmur can be heard. The incumbent bike puts the back and neck of the patient in a more convenient position for assessing the TERC murmur. The exercise bike is set to the lowest resistance; exertion level is mediated by rate.

Auscultation is performed at the carotid notch on both sides (Clark et al., 2016, Jahangiri et al., 2015, Kurtz 1990, Lucerna 2020). See also, Figure 1. At rest there should be no TERC murmur heard. Note – A bruit heard at rest can be a sign of cardiovascular disease and should be

referred to a physician immediately. Breath sounds can often be heard at this location (Lucerna 2020). Some textbooks recommend auscultating while a patient holds their breath. (Lucerna 2020). Breath holding is not recommended for an exercising patient in this protocol. Therefore, it may take practice to hear the TERC murmur between breaths. A symptom check is performed prior to the test. The results are typically collected with Table 1. The heart rate taken before the test begins serves as the baseline heart rate.

Figure 1

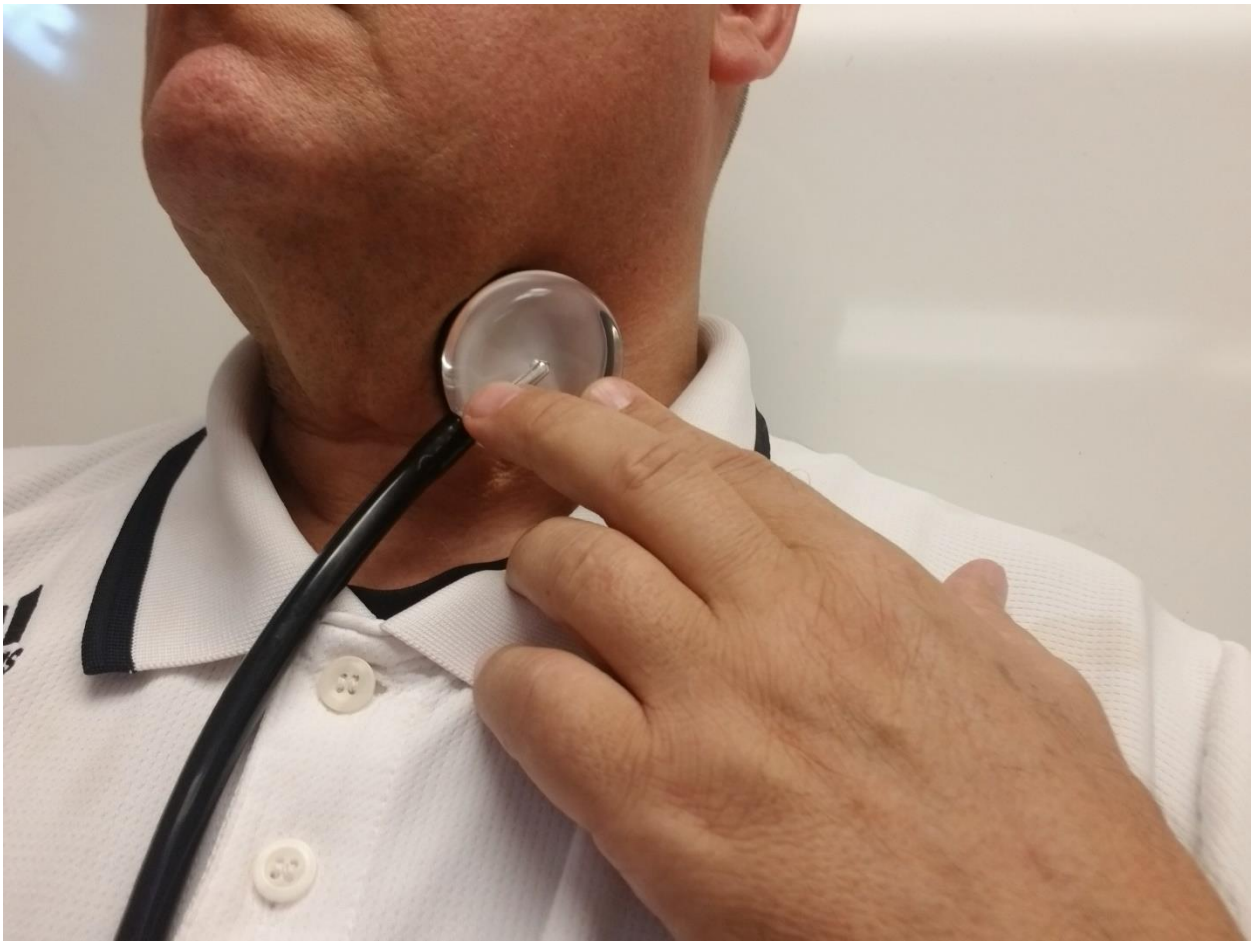

Figure 1 legend. In this figure we demonstrate the placement of the stethoscope over the left carotid notch.

Table. 1. Data Collection Template

Time *	Heart Rate (BPM)	Left Carotid *	Right Carotid *	Symptoms #	Other comments*

TABLE 1. SAMPLE DATA RECORDING TOOL FOR ASSESSING TERC MURMUR

*TERC murmur is generally scored as present or absent.

#Symptoms are self-reported.

In Clark et al., the mean heart rate for hearing the TERC murmur was 150 BPM in healthy uninjured individuals and the TERC murmur tended to occur around 120 BPM in the post-concussion individuals (Clark et al., 2016). The rate used here is 140 BPM because 150 BPM was the mean heart rate to appreciate the TERC murmur. Most healthy athletes will have a normal physiological TERC murmur initiate with a heart rate above 140 BPM.

The exertion instructions are presented to the patient before they start pedaling. To begin with phase 1, the patient should pedal like they are performing 1 or 2 minutes of a light warm up, such as a jog around the track before a practice. Heart rate, TERC murmur and symptoms should be monitored and documented at each exercise phase. The goal is to collect auscultations as the heart rate increases. Other observations such as face flushing, change in demeanor, axillary sweat, and facial sweat should be noted. The examiner tells the patient when to progress to the next phase, once the data (heart rate, TERC murmur, symptoms et cetera) have been observed

and recorded. Each phase can be performed with two or more athletic trainers within 1 minute. If a single person is conducting the test, it often takes approximately 2 minutes at each phase.

Exertional phase 2 is a slightly higher exertion achieved by increasing the cadence; this rate is between the phase 1 speed and the phase 3 speed. Phase 2 lasts 1 to 2 minutes. All parameters are collected again.

Exertional phase 3 is analogous to fat burning cardio for that patient (Zone II, HR <65%), based on age and gender maximal heart rate. For the patient, this is explained as an exertion level that they feel they could maintain for one hour or more. During the instructions, these levels are explained to the patient so they can make their own decisions on exertion levels and pedaling rates. As the independent variable we are interested in is the heart rate, the exertion level can be modified as needed to achieve desired heart rate. If the heart rate reaches 140 or above without symptoms and without TERC murmur being heard the exam can be concluded. If after about 5 minutes the heart rate has not reached 120 or above the patient can be encouraged to increase the intensity.

A 1-minute sprint can be performed if the heart rate has not achieved a heart rate greater than 120 BPM after 8 minutes, assuming the absence of symptoms and the TERC murmur. During the sprint we monitor heart rate continuously with rates reported every 15 seconds and the TERC murmur monitored continuously as well. This is dependent upon the skill and availability of personnel and the fitness level of the athlete.

The sprint continues until the heart rate exceeds 140 BPM or if it is felt that a sufficient target heart rate has been achieved. Remind the patient that with low resistance on the bike a full sprint is not easily feasible, so fast but safe is strongly recommended.

If there is an absence of a TERC murmur and the heart rate exceeds and sustains 140 BPM for 1 minute the exam can be concluded. The test typically can be completed in approximately 10 minutes.

If the TERC murmur is heard and sustained (30 seconds over 2 assessments) the test can be concluded. For example, if the last heart rate without a TERC murmur was 116 bpm and the TERC murmur was heard at 120 BPM, then the target HR for the exercise prescription would be

116. Continue to interact with and observe the patient to ensure no delayed symptoms or issues after the conclusion of testing.

TERC Murmur Assessment for Strength Training

The strength training assessment includes two separate stages with the TERC murmur assessed at the end of each stage. If the TERC murmur is heard at either stage the exam is concluded.

Stage 1

The patient is instructed to do three sets of ten push ups, ten sits up, and ten air squats, in this order, using the technique most familiar to them. These exercises should be done with a cadence of one per second. The examiner observes the technique, because poor muscle memory or poor technique could indicate a risk for strength training (athletes should be familiar with these exercises). Following the exercises, the patient stands facing the examiner. The examiner evaluates for impaired coordination, balance, or posture. He/she then auscultates the carotids and obtains heart rate by palpation at the radial artery. TERC murmur with a heart rate of less than 140 BPM is a positive test.

The patient is instructed to do the pushups, sit ups and air squats in a consistent way using the methods most familiar to them. As stated earlier the athletic trainer will know his or her athlete and that this test is for experienced athletes. Poor technique or poor muscle memory could indicate that the patient might be at risk of injury when lifting and should be taken into consideration when considering a lifting prescription.

If inconsistent technique, poor muscle memory or TERC murmur heard below a heart rate of 140 BPM is observed, the test would be considered positive and lifting at this time should be considered contraindicated. Good posture, good technique, lack of symptoms and lack of

TERC murmur suggest a negative test and that the test can be progressed at that time to the next phase.

Stage 2 Of the Strength Training Exertion Test

Stage 2 of the strength exertion test consists of the use of the back-arch equipment. Stage 2 should not be completed if the patient did not pass the cardiovascular exertion and the Stage 1 of strength training, or if he/she is not familiar with the back-arch equipment. The patient should again be familiar with the equipment. This test can be done shortly after the Stage 1 of the strength assessment.

The patient adjusts the size for the back-extension equipment, mounts the equipment and hangs his/her head down such that the head is lower than the rest of the body. The examiner asks about headache or other symptoms. In the absence of symptoms, the athlete is instructed to do one back arch and hold his/her gaze on the examiner. The hold is only for 2 or 3 seconds to ensure safety, stability, and ability to do the test. If the gaze is stable and no contraindications are noted, the athlete continues to do nine more back extensions. At each extension, the examiner and athlete make eye contact to ensure lack of symptoms or dysfunction. The cadence is approximately 1 second down and 1 second up. Once completed, the athlete dismounts and stands facing the examiner. The athlete is observed for impaired coordination, balance, posture and gaze while looking at the examiner. Following, the examiner listens for the TERC murmur and obtains the heart rate. An absence of TERC murmur or no TERC murmur below a heart rate of 140 BPM is a negative test.

Results

We screened 132 patient visits and identified 71 subjects who met the inclusion criteria and were included in this study. There were 71 cardiovascular assessments and 19 patients who also underwent a strength training assessment.

The most common symptoms reported in decreasing order of frequency was; headache, feeling not right, cervicogenic, photophobia, fatigue, dizzy/dizziness, phonophobia and tinnitus. These were reported prior to the assessment. No subjects reported symptom exacerbation during the test. Headache is the most common symptom. Patients often report feeling down, not right, not 100% and we designate this as feeling Just No Right (JNR). JNR is a common complaint where post TBI patients express something is not normal for them, but they are unable to express it clearly. It becomes somewhat of a subjective complaint that indicates an ill-defined deficiency.

Results from Assessments

We found that 73.4 percent of the 71 cardio assessment athletes had a TERC murmur. The mean TERC murmur was (M = 127.3, SD = 16.2) BPM. Based on these results we recommended an average target heart rate for the exercise prescription of (M = 119.3, SD = 11.0) BPM. For this cohort the resting heart rate was (M = 75.1, SD = 13.5) BPM. For the 19 strength assessments performed, we found that 42.1% experienced a positive TERC murmur. Fifty-two athletes received and followed exercise prescriptions without report of adverse events.

If a positive test was observed the patient would be closely monitored while performing the exercise prescription. When the physician of record and / or the athletic trainer requested a repeat exertion exam it would be repeated when needed.

Discussion

The current study provides evidence that supports the use of TERC murmur reflex as an objective measure to determine HR for developing an exercise prescription post-concussion. A benefit of the TERC murmur is that it does not rely on subjective reporting from the athletes. Exercise and exertion post-concussion is an integral part of essentially all return to play protocols (Makdissi et al., 2014, Harmon et al., 2013 Simon et al., 2009). There are insufficient data or methodology for the sports medicine professionals to make objective decisions concerning appropriate levels of participation/exertion/exercise after injury. We believe that the TERC murmur for cardiovascular and lifting progressions is a simple means of aiding the return to play decision status post-concussion.

Personal Clinical Experience

Athletes who are removed from sports/physical activity following a concussion may take a while to return to play, which can lead to a decrease in their physical abilities/skills and also psychological difficulties, which can then have a negative impact on recovery. Therefore, training, even at a very low level, may be beneficial. Often these athletes have been restricted from exercise in an abundance of caution for various reasons. When performing the exertion assessment and closely monitoring the athlete we believe that the athletes are happy to get a chance to start doing some conditioning. Even when we must give restrictions of a target heart rate of as low as 90 BPM (generally somewhat faster than a brisk walk) the athlete is still very happy to be able to start being more active. The TERC murmur can be used at any exertional phase but please also recall that Clark et al., reported that the mean heart rate for the TERC murmur to be heard is 150 BPM in normal healthy adults (Clark et al., 2016). So do not expect that it will always be absent in a conditioned athlete or normal healthy adult. Elevated heart rates will generate the TERC murmur in healthy individuals.

Auscultation is a skill taught to many clinical disciplines. Many of us with neuro expertise are trained to auscultate the cervical notch or carotid artery for evaluating bruit, breathing and swallowing (Pelisek et al., 2016, Knapp et al., 2014, Kartchner et al., 1969). These methods are extremely well established with multiple reports concerning reliability (Pelisek et al., 2016, Knapp et al., 2014, Kartchner et al., 1969), but they are a skill that requires experience and practice. Even with skilled practitioners the reliability can range from 60% to 85%.

We proffer an anecdote to support our claims. One athlete post-concussion was being assessed on the exercise bike and the exam was discontinued when the TERC murmur was heard. This is following the protocol presented above. At the time the athlete denied symptoms, had no change in comportment and no change in observable symptoms. Notwithstanding, the exercise prescription and target heart rate was formulated based on the TERC murmur and last heard normal heart rate. Months later the athlete confessed that she had misrepresented her being asymptomatic during the exam. She claimed that immediately before the exam was concluded that her headache and other symptoms (photophobia) came back, but she wanted to get back to play so she claimed everything was okay. She confirmed that the test and target heart rate worked for her as she used the target heart rate without symptoms and without incident during her return to play progression.

To date we have had no serious adverse events or setbacks reported from athletes who used our target heart rates and exercise prescription as part of their rehabilitation and return to play. We believe that the clinical advantage of this methodology is that it provides objective information for making clinical decisions and that faster return to safe exercise is associated with a faster return to play.

Sample Exercise Prescriptions

Below we present a sample exercise prescription. It is recommended that the athletic trainer or sports medical professional making decisions concerning an exercise prescription take into consideration, the patient's training level, their needs, their sport/position, pervious or concomitant injuries as well as contraindications concerning exercise or activity.

In the initial phases of cardiovascular conditioning the athlete is advised to do low impact cardio such as biking, riding the elliptical, or exercising on a similar machine in an upright fashion for 20 minutes. After 20 minutes the athlete stops and does a whole-body assessment. For the purposes of educating the athlete, we use a simple rhyme: assess "fingers toes, head neck and nose". The athlete is instructed to determine if they feel numbness, tingling or fullness in the fingers or toes. Toes also implies feet and balance assessment. Head is to assess for head pain and posture. Neck is to assess cervicogenic symptoms, range of motion and posture. Nose is to assess sinuses or congestion and has a double meaning. Nose also implies KNOWS; they are to confirm with an athletic trainer or designee that they are okay and can continue for another 20 minutes, so someone else KNOWS they are okay. Typically, we have the athletes do two to four 20-minute bouts. This is dependent upon conditioning needs of the patient or athlete. Between the 20-minute bouts, the athlete can also switch machines as they wish.

If an athlete achieves a heart rate exceeding 140 BPM in the absence of TERC murmur and symptoms, the exercise prescription would be the same as above. In addition, there would be no heart rate maximum. Instead, a fat burning heart rate target consistent with age, gender, sport and conditioning would be recommended.

Heart rate can be increased empirically or with subsequent assessments of TERC murmur. For example, it is not uncommon for an inquisitive athlete to request a "listen" to see if they are able to get their heart rate up higher as rehabilitation continues. We recommend that one listens as the heart rate rises not as it falls.

Exercise Prescriptions for Strength Assessment

If there is an absence of TERC murmur following the three sets of ten, an athlete is likely to be safe to be cleared to participate in antigravity types of conditioning and resistance bands. Typically, high reps with moderate weights or antigravity can be engaged. Again, we target 20-minute sessions with the "fingers toes head neck nose/KNOWS" rhyme.

If the athlete passes the back-extension assessment as well, the athlete can likely be cleared for return to lifting. Typically, a staged return to lifting would occur. This could include

antigravity and non-core conditioning. We recommend a first lifting session without maximal weights and without core-based lifts: no loaded squats, bench press or leg presses. If asymptomatic during lifts the athlete can progress in the next lifting program to a more complete lifting session. Reported symptoms, dizziness, and balance difficulties should be reported and the lifting scaled back as needed to minimize symptoms.

We have investigated the utility of listening for the TERC murmur to begin as heart rate increases as well as to listen for it to subside as the heart rate falls. We feel that the initiation of the TERC murmur is representative of a protective mechanism relevant to making exertional determinations. We believe that these methods and the results supporting the use of the TERC murmur adds to the body of literature and evidence-based medicine to aid in safe return to exertion and eventual return to play for the athlete who is a concussion patient.

Limitations

There are several limitations of this study. First, it is a retrospective chart analysis. As such there is no control group and we did not correct for confounding variables such as different sports, different severity of injury et cetera. Control data from norms can be found in the literature (Clark et al., 2016). Future studies such as a prospective study are required. This study is limited to active athletes. Therefore, it is not recommended to use these methods on individuals who are not physically conditioned. This study has a relatively small sample size making the extension of these results to a broader population difficult. The tests were performed on an incumbent bike because of easy access to the neck and as it minimizes background noise that obscures hearing the TERC murmur. We cannot address the utility of the TERC murmur on other platforms. Another limitation of this study is that the current study is not compared to the current gold standard, the Buffalo treadmill test (Leddy et al., 2019 a and b). Future studies should be considered to address this.

Conclusion

Controlled cardiovascular exercise intervention is commonly implemented as part of a return to play protocol (Leddy et al., 2019 a and b). However, the level of exertion suggested by the referenced protocols are based on self-reported symptoms. The current study provides support for the objective assessment of TERC murmur to determine target HR for both cardiovascular and strength training. We believe that these methods will allow patients to return to athletics safer and likely sooner.

Acknowledgements

This work was not supported by any grant funding.

The authors have no financial interests to disclose.

Key Words

Concussion, Exertion, Exercise test, Exercise Prescription, Bruit, TERC Murmur, auscultation, stethoscope, exercise bike, strength and conditioning.

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Supplemental Material.

In this supplemental material we demonstrate and discuss a sample TERC murmur assessment on a healthy volunteer. Jon Vincent is in a recumbent bike and Nicole Giordano is taking heart rate via radial pulse and the TERC murmur via both carotids.