INTER-RATER RELIABILITY OF DYNAMIC EXERTION TESTING (EXiT) PERFORMANCE AMONG HEALTHY ADULTS

by

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INTRODUCTION: The Dynamic Exertion Test (EXiT) is a new standardized return to play (RTP) exertion assessment for athletes at medical clearance following a concussion. It incorporates aerobic, multiplanar dynamic, and functional movements, based on exercise prescription guidelines from the American College of Sports Medicine (ACSM), with objective measures that work to challenge all potentially affected systems of a concussed athlete. The purpose of this study is to determine the interrater reliability (IRR) of the EXiT between two raters assessing healthy, non-concussed athletes and to determine the level of systematic bias between the two raters. **METHODS:** A subgroup of 15 participants (F=5, 33.3%, age: 23.67 ± 4.22 years old) from a larger study were assessed with the EXiT on two visits. Two raters simultaneously scored participants at both visits on the number of errors committed on all dynamic tasks and on time to completion on agility cone tasks. IRR was estimated using intraclass correlation coefficients (ICC) and 95% confidence intervals (CI) for time and Kappa Coefficients and 95% CI were used for errors. Paired t-tests and McNemar Tests were used to assess for systematic bias between raters' scores. **RESULTS:** Time to completion had good IRR (ICCs > 0.759), Arrow Agility at visit 1 had the highest (0.999 [95% CI 0.997-1.0]) and Box Drill Carioca at visit 2 had the lowest (0.759 [95% CI 0.314-0.929]). Fifteen of the 20 tasks showed no statistically significant difference between raters scores. Errors had poor to excellent IRR (p-values: 0.324-1.00) and an observed percent agreement >83.33% for 10 of 14 tasks, Zigzag at visit 1 had the lowest (66.66%). McNemar Test showed no statistically significant difference (p-values > 0.250) for all task errors, but Arrow Agility had the largest difference between raters at both visits (13.33% vs. 40%, 16.66% vs. 41.66%). **CONCLUSION:** IRR for the EXiT time and errors was good for the majority of tasks. This study was a good first step in evaluating the reliability of the new RTP exertional protocol, the EXiT. Future research should use a larger sample size to evaluate IRR in concussed participants along with intra-rater and test-retest reliability.

Table of Contents

List of Tables

Preface

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1.0 Chapter 1

1.1 Introduction

Sports related concussions (SRC) are temporary neurological injuries caused by a direct blow to the head or other part of the body that induces a force transmitted to the head.[1] SRC are a growing health concern as it is estimated that 1.6 – 3.8 million SRC occur every year.[2,3] Concussions are a heterogeneous injury and a concussed person may present with several different symptoms or impairments including physical, somatic, cognitive, vestibular, emotional, and sleep-related impairments.[1,4-7] Thus expert consensus advocate for the multifaceted and individualized management of concussion injuries.[1,8-10] Diagnostic evaluations assess signs and symptoms, mental status, cognitive functioning, sleep disturbances, ocular and vestibular functioning and balance and gait impairments.[1] Results from these assessments are used to develop individualized treatment strategies, especially in patients who have prolonged recoveries (>14 days).[1,9,10] Research supports treatments like psychological, cervical and vestibular rehabilitation for those with ongoing symptoms,[1] along with new evidence suggesting that after an initial 24-48 hours of rest, gradual submaximal activity, while staying under their symptom-exacerbation threshold, is safe and potentially beneficial for concussed people.[1,10-14] When determining return to play (RTP) readiness following a concussion there is currently no gold standard assessment that includes objective measures of all potentially impaired systems. Current protocol is based on expert consensus and includes a graduated series of steps that steadily increase activities over 24-hour periods.[1,12] However this approach is limited in that the sport type or athletes' gender are not considered,[15] and the exercises performed are vaguely described, accounting for highly variable approaches between administers.[16] In addition, progression through the protocol is reliant on self-report symptoms alone, which athletes may underreport.[1,8,17,18] Since submaximal exercise is considered safe and potentially beneficial for concussed people,[1,10-14] is it thought that higher levels of exercise may be used to determine RTP readiness.[19]

Several exertional tests have been developed,[19-21] with the Buffalo Concussion Treadmill Test (BCTT) as the most widely used. The BCTT was developed for determining the level of aerobic exercise that a concussed persons can perform while staying under their symptom limited threshold.[11,22-24] The BCTT consists of uniplanar aerobic running on a treadmill[19] and newer exertional tests are being developed as RTP assessments and are including multiplanar dynamic movements that more accurately replicate movements performed during sport.[20,21] Inclusion of multiplanar dynamic movements is important as these movements tend to perturb the vestibular system,[25-29] which is a commonly impaired system in concussed athletes.[5,7,30-35] However, these exertional tests, like the graduated RTP progression lack rational for the exercise prescription chosen and rely on the subjective reporting of symptoms to determine a successful test. The Dynamic Exertional Test (EXiT) was designed as a standardized RTP exertion assessment for athletes returning from a SRC. The EXiT incorporates aerobic, multiplanar dynamic, and functional movement exercise prescriptions based on the American College of Sports Medicine (ACSM) guidelines[36] and has objective measures of time to task completion and errors made, along with symptom reporting (STUDY19080194). The reliability of a health care assessment is important as the results of any one assessment should be consistent across different clinicians so that an informed clinical decision can be made. The interrater reliability (IRR) of EXiT is still unknown, thus the purpose of this study is to determine the level of agreement between two clinicians, or raters, (the IRR) when assessing healthy athletes performing the EXiT.

1.2 Sports Related Concussions

1.2.1 Definition and Pathology

The Concussion in Sports Group (CISG) define concussion as a traumatic brain injury induced by biomechanical forces caused by a direct blow to the head, face, neck or elsewhere on the body with a force transmitted to the head. The CISG further state a concussion can result in the rapid or gradual onset of neurological functional impairments and may or may not involve loss of consciousness.[1] These forces cause cell membranes to be disrupted and axons to be stretched, resulting in an efflux of ions, rapid depolarization and the release of numerous neurotransmitters. When this happens, Sodium/Potassium (Na/K) ATP-dependent pumps try to reestablish ionic balance causing energy stores to become depleted. This cascade of alterations in neurotransmitters, glucose metabolism, cellular ions, and cerebral blood flow (CBF) are believed to be responsible for the signs and symptoms and the cognitive, somatic, and emotional dysfunctions observed in concussed athletes. [12,19,37]

1.2.2 Epidemiology

The Centers for Disease Control and Prevention (CDC) estimated that 283,000 children visit the emergency department for a SRC each year.[38] Bryan et al.[2] have generated the most up to date national estimate of SRC in children ≤18 years old. In 2013 they collected data from emergency departments (National Electronic Injury Surveillance System), primary and subspecialty care (MarketScan). They also collected data from high school athletic trainers (High School Reporting Injury Online) to ensure that SRC that did not result in an encounter with additional health care providers were included. From this data, they estimated that 1.1 to 1.9 million SRC occur annually in US children, including those who go undiagnosed. Langlois et al.[3] estimated that 1.6 – 3.8 million TBIs related to sports injuries occur every year, including those for which treatment is not sought.

Kerr et al.[39] evaluated concussion rates in 20 high school sports over 3 academic years (2013-2014 to 2017-2018). They found an overall concussion rate of 4.17 per 10,000 athlete exposures (AEs) with more occurring during competitions than practices (10.37 vs. 2.04 per 10,000 AEs). Football had the highest rate, with girls' soccer having the second highest, followed by boys' ice hockey (10.40 per 10,000, 8.19 per 10,000, and 7.69 per 10,000 AEs, respectively). Zuckerman et al.[40] described the epidemiology of concussion rates in 25 National Collegiate Athletic Association (NCAA) sports over 3 academic years (2009-2010 to 2013-2014). They found concussions made up 6.2% of all reported injuries with an injury rate of 4.47 per 10,000 AEs with more occurring during competition than practice (12.81 vs. 2.57 per 10,000 AEs). Wrestling had the highest rate, followed by men's and women's ice hockey, football and women's soccer (10.92 per 10,000, 7.91 and 7.50 per 10,000, 6.71 per 10,000, and 6.31 per 10,000 AEs, respectively). While concussion rates were much higher during competitions compared to practices in nearly all sports, the frequency of concussions that occurred during practices were higher than during competitions in 13 of the 25 sports, including football. Dompier et al.[41] evaluated the incidence of concussions in football players across three levels (youth, high school, and collegiate) over two academic years. They found that college football had the highest competition rate (3.74 per 1000 AEs) but the lowest practice rate (0.53 per 1000 AEs). Competition rates were higher than practice rates for all three levels, however, they also found that more concussions occurred during practices compared to competitions.

1.2.3 Diagnosis/Evaluation

Concussed persons may present with several different symptoms, including physical (neurological deficits, amnesia, loss of consciousness, neck pain), somatic (headache, fatigue, nausea), cognitive (reaction impairments, memory, feeling in a fog), vestibular (dizziness, balance, blurred vision), emotional (irritability, depression, anxiety), and sleep-related impairments.[1,4-7] Headache is the most commonly reported symptom (74% to 98%) of athletes with a SRC. Other commonly reported symptoms include dizziness (50-84.1%), difficulty concentrating (54-61.2%), balance impairments (40-80%), fatigue/ low energy/ drowsiness (26.5-63.3 %), nausea/vomiting (28.9-55.1%), and vision impairments (25.5-39.8%).[32,33,35,42]

Due to the heterogenous clinical presentation of concussion, expert consensus advocates for a multifaceted assessment,[1,8] and being able to quickly and accurately diagnosis a concussion is crucial to an athlete's health and recovery. SRC evaluations rely on thorough neurological testing. This includes an evaluation of signs and symptoms, mental status, cognitive functioning, sleep disturbances, ocular and vestibular functioning, and balance or gait impairments.[1] The most common concussion assessments are those that evaluate symptoms, cognitive function and vestibulospinal function (balance).[17,18]

Self-reported symptom checklists, such as the Post-Concussion Symptom Scale (PCSS) and Neurobehavioral Symptom Inventory (NSI), are clinically intuitive to evaluate athletes for common concussion-related symptoms. These assessments have been shown to accurately identify SRC in athletes, with a sensitivity of 64%-89% and a specificity of 91%-100%.[8,43] However, there are some notable limitations in relying solely on self-reported concussion symptoms. For instance, some concussion-related symptoms may be related to other non-concussion factors, or athletes may underreport symptoms for fear of being removed from play or losing their position on the team.[1,8,17,18] Not only may symptoms be underreported, but it has also been found that symptom resolution may occur before cognitive recovery, thus computerized neurocognitive assessments, such as the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), have become increasingly popular and have proved to be an important and reliable addition to the concussion evaluation process.[1,17,44,45] Balance and postural, assessed via Balance Error Scoring System (BESS) and modified BESS (mBESS), are another common domain tested in athletes with suspected SRC assessments. Balance is considered somatosensory and relies on the vestibulospinal system for proper function. While both neurocognitive and balance assessments are key domains in the evaluation of athletes with a suspected concussion both have been proven unreliable when an athlete is in an exerted or fatigued state and are not a recommended sideline assessment.[46-50]

The most common sideline assessment is the Sport Concussion Assessment Tool (SCAT). [1,8,51] The SCAT, now on its fifth revision, is a combined assessment that evaluates symptoms via the PCSS, standard orientation questions via Maddocks score, traumatic brain injury severity via the Glasgow Coma Scale (GCS), and a physical and cognitive evaluation (working memory, concentration, remote memory, balance, and coordination).[8,51] The SCAT5 is currently the most well-established and rigorous test for sideline concussion assessment and is shown to be very reliable in identifying concussions immediately after the injury, however its accuracy decreases 3-5 days after the initial injury.[1] The King-Devick (KD) test and the Vestibular-Ocular Motor Screen (VOMS) are newly developed concussion tools that assess the vestibular and ocular-motor system, a system that is only partially evaluated in the SCAT and BESS. The KD test is a quick evaluation of saccadic eye movements, measuring the time it takes an athlete to read three test cards with a variety of numbers at different visual difficulties. A baseline score is needed for this test and a decreased reading speed, when compared to the athletes' baseline, is indicative of a concussion.[8,51,52] The VOMS is a brief clinical screening tool used to asses vestibular and ocular motor impairments and symptoms after a SRC. It consists of 5 domains: smooth pursuits, horizontal and vertical saccades, convergence (near point convergence [NPC]), horizontal and vertical vestibular ocular reflex (VOR), and visual motion sensitivity (VMS). Athletes rate their symptoms (headache, dizziness, nausea, and fogginess) from 0 (no symptom) to 10 (severe symptom) after each domain test is completed. Smooth pursuits measure one's ability to follow a slowly moving target with their eyes while keeping their head still and saccades measures the ability of the eyes moving quickly between two targets while the head is still. Convergence is measured by NPC test, which measures one's ability to view a near target without having double vision. VOR measures one's ability to stabilize their vision on a target while their head is moving, and VMS is a measure of one's ability to inhibit vestibular-induced eye movements while using vision. Any VOMS symptoms score ≥2 or a NPC ≥5cm is indicative of a concussion.[5] Both the KD and VOMS are reliable in identifying concussed athletes in a rested state,[5,52,53] but their reliability on the sideline is currently unclear.[29,54]

1.2.4 Treatment/Rehabilitation and Recovery

Due to the wide variety of symptoms associated with SRC, it is considered a multifaceted injury which needs an individualized treatment strategy.[9,10] Rest until patients are asymptomatic is the commonly prescribed treatment for those with SRC and is the consensus among experts.[1] However, there is insufficient evidence to support complete rest,[1,55,56] and new evidence suggests that after an initial 24-48 hours of rest, gradual submaximal activity, while staying under their symptom-exacerbation threshold, is safe and potentially beneficial for concussed people,[1,10-12] contributing to faster symptom resolution[11,57] and decreased physical and emotional symptoms.[57]

A new concept emerging in individualized concussion management is "clinical profiling". This model includes six different trajectories a concussed person may follow: cognitive/fatigue, vestibular, ocular, posttraumatic migraine, anxiety/mood, and cervical/sleep as modifiers. Concussed persons may be classified under a single profile but typically present with a combination of profiles.[12,34,58] In a recent study of 236 concussed athletes 35% had a primary profile of ocular or vestibular, 26% had migraine, 24% had anxiety/mood, and 11% had a primary profile of cognitive/fatigue. Cognitive/fatigue profiles are characterized by difficulty with thinking skills and pronounced fatigue when attempting mental activities. Symptoms typically worsen throughout the day and can include trouble concentrating, memory problems, feeling mentally slow or foggy, and having low energy levels or fatigue. Those with cognitive/fatigue profiles may benefit from behavioral regulations, medications with stimulant properties or accommodations at school/work. Anxiety/mood profiles are characterized by emotional and behavioral changes such as depression, anxiety, feeling more emotional, irritability, moodiness, or have sleep dysregulations following the concussion. It is important to note that athletes may exhibit these behavioral changes rather than report them. However, they may report other symptoms inconsistently, have discrepancies on objective neurocognitive testing or have worsening symptoms overtime. Anxiety/mood primary profiles are associated with migraine profiles and may benefit from psychotherapy approaches and/or psychotropic medication.[34] Headache is the most commonly reported symptom following a SRC (74% to 98%).[32,33,35,42] Most athletes have a headache in the first week of injury, however those with a migraine profile experience a persistent, intermittent headache beyond the first week. Other associated symptoms with a migraine profile include sleep dysregulations, anxiety/mood disturbances, and worsening headache when under stress or during physical activity. Migraine primary profiles are associated with vestibular and anxiety/mood profiles and may benefit from behavioral regulation or referral to a headache specialist. One third of the concussed population had an ocular or vestibular profile.[34] Ocular profiles are characterized by vision impairments with symptoms like blurred or double vision, trouble focusing, frontal headache/pressure, or fatigue when reading or doing computer work. Vestibular profiles are associated with symptoms like dizziness, lightheadedness, imbalance, fogginess, or nausea. Concussed persons with a vestibular profile may be asymptomatic at rest but experience symptom provocation during dynamic activates, car rides, or in crowded environments. Ocular primary profiles are associated with cognitive/fatigue profiles, while vestibular primary profiles are associated with migraine and ocular profiles. Both ocular and vestibular profiles may benefit from vestibular rehabilitation, visual-training exercises, and/or exposure/recovery therapy such as performing daily activities or visually demanding tasks.[34] Cervical profiles may benefit from manual therapy and/or head/neck proprioceptive rehabilitation.[10,34] Matching athletes' clinical profile to targeted, active interventions may improve recovery trajectories.[10]

Aerobic exercise is beneficial for the autonomic nervous system, cerebral blood flow, CO_2 sensitivity, mood, sleep,[12] cardiovascular physiology, and brain neuroplasticity, so it is thought that aerobic exercise could assist concussed persons in recovery.[11,19] New evidence has shown that gradual, submaximal exercise, while staying under symptom exacerbation threshold, is safe and potentially beneficial for concussed people.[1,10-14] A recent study found that 20-minutes of light aerobic exercise each day compared to a stretching program helped recently concussed (<10 days) athletes recover significantly faster.[11] It is also believed that aerobic exercise may assist those suffering from prolonged symptoms to recover[14,24,59,60] and decrease the overall occurrence of prolonged recovery (>30 days) in concussed persons.[11] Leddy et al.[61] evaluated 12 patients with prolonged concussion symptoms (mean of 19 weeks) for 2-3 weeks before beginning a standardized exercise protocol of 5-6 times per weeks at 80% maximum heart rate (HR) from their baseline exercise test. No participant improved over the initial 2-3-week rest period, but participants symptoms improved significantly over time during the exercise protocol. Kurowki et al.[62] randomized 30 adolescents who suffered a mild traumatic brain injury (mTBI) and were experiencing persistent symptoms (4-16 weeks) into either an aerobic cycling program or full body stretching program. The cycling group reported lower symptoms at all time points and had significantly improved symptoms at the end of the nine-week intervention compared to the full body stretching group, with a moderate to large effect size (Cohen's d .51 -.81).

It is important to keep in mind that because of the heterogeneity of concussions there is no single treatment strategy that can be effective for all concussed persons. Multiple different active rehabilitation strategies can be combined to match specific impairments and symptoms to assist recovery.[10,34] Most athletes recover from SRC in 1-2 weeks [1,10,30,35] but those with vestibular-ocular, sleep and migraine profiles have been associated with longer recoveries.[31,32,34] Research supports treatments like psychological, cervical and vestibular rehabilitation for those with ongoing symptoms,[1] along with new evidence showing the potential of aerobic exercise for those experiencing prolonged recovery.[14,24,59-62] Determining when an athlete is fully recovered and able to safely begin normal activities again is very important and should be as individualized as their treatment.[12]

1.3 Return to Play

The CISG recommends that athletes do not RTP the same day as a concussion and complete a progression through a graduated series of steps before full medical clearance for RTP is given.[1]

A recent study compared data from the NCAA Concussion Study (1999-2001) to the current NCAA-DoD CARE Consortium (>2014), both large prospective studies evaluating RTP for SRC in collegiate football players. The CARE cohort was symptom free for a significantly longer time before returning to play compared to the NCAA cohort (7.25 vs. 3.25 days respectively) and had an overall longer RTP time (m = 16.08 days). Their results show that the current concussion management techniques, like those recommended by the CISG and evaluated in CARE, are reducing the risk of within-season repeat concussion (3.85% repeat in CARE vs. 6.52% repeat in NCAA),[63] but this protocol still has several critical limitations that reduce its effectiveness.[1,8,15-18]

1.3.1 Staged Return to Play

Currently, the CISG's graduated return-to-sport strategy includes 6 stages of varying activity levels, they proceed as follows. After an initial period of rest (24-48 hours) the athlete can begin the first stage; symptom limiting activity, which can be any activity that does not provoke symptoms such as reintroduction of school or work activities. Once the athlete is asymptomatic, they can progress onto the second stage, light aerobic exercise, such as walking or stationary cycling. Stage three is sport-specific exercises, stage four is non-contact training drills, stage five is a full contact practice, and stage six is return to normal game play. The CISG states that each of the 6 stages should only take 24 hours so an athlete could expect to move through the protocol in one week, assuming they complete each stage without a recurrence of symptoms. If the athlete experiences any concussion-related symptoms during a level, they should discontinue the activity and attempt the level again after being asymptomatic for 24 hours at the previous level.[1,12] While many practicing certified athletic trainers use this graduated RTP protocol and consider it a valuable tool when making RTP decisions,[64] there are several limitations that reduce its effectiveness. The duration, exercise type, and intensity of each stage is vaguely described, which leaves highly variable approaches between administering clinicians.[16] It also does not consider the sport type or athletes' gender[15] and progress through the protocol is reliant on self-report symptoms alone, which athletes may underreport.[1,8,17,18]

1.3.2 Structured Exertion Tests

Since submaximal exercise, while staying under symptom exacerbation threshold, is considered safe and potentially beneficial for concussed people,[1,10-14] it is thought that higher levels of exercise may be used to determine physiologic recovery and RTP readiness.[19] The BCTT was developed for determining the level of aerobic exercise that a concussed person can perform while staying under their symptom limited threshold. It is an adaptation of the Baalke treadmill test, which is used to determine maximal oxygen consumption in sedentary individuals,[19,61,65] and is currently the most widely used exertion test for SRC, in acute and subacute patients.[11,22-24] The BCTT begins at 3.6 mph at a 0.0% incline (the speed can be altered for taller or shorter athletes as needed). At 2 minutes the incline is increased by 1% and then by 1% each minute thereafter, maintaining the starting speed of 3.6 mph. Throughout the assessment, rating of perceived exertion (RPE, Borg scale) and symptoms are measured every minute and HR and BP are measured every 2 minutes. Exercise is terminated if the athlete has significant symptom exacerbation (≥3 points from that day's baseline scores on a 10-point visual analog scale [VAS]) or at exhaustion (RPE of 19 or 20). If the athlete reaches the maximum treadmill incline and can continue without exacerbation of symptoms or exhaustion, the speed is increased by 0.4 mph every minute until termination criteria is fulfilled.[19] The BCTT is safe for persons with a concussion and has high

IRR, with a sensitivity of 99% and specificity of 89%, and good retest reliability (RTR) for HR when identifying symptom exacerbation in patients who are my ready to RTP following a SRC.[65] Orr et al.[21] determined that a modified Bruce treadmill is safe and can predict protracted recovery in children and adolescents with a SRC. For their protocol they used the same grades as the Bruce but increased the speed of every stage. This was done because the Bruce protocol, compared to the Baalke, reaches higher running speeds sooner, allowing for shorter testing periods and reduced the risk of boredom for athletes. Their modified Bruce protocol begins at 10% incline and 2.8 mph for 3 minutes, and both incline and speed progressively increase every 3 minutes thereafter (treadmill incline, speed [mph.]; (12%, 4.0), (14%, 5.5), (16%, 6.2), (18%, 8.1), (20%, 8.9)). Throughout the protocol (end of each 3 min stage) HR, RPE, and symptom severity were recorded. Exercise was terminated if the athlete asked to stop, demonstrated a significant gait impairment, loss of balance or coordination, abnormal HR response, or reported a symptom increase >3 points. Athletes with an exercise duration of <9 minutes were 3 times more likely to have a prolonged recovery (OR, 3.1; 95% CI, 1.2-8.5).

Kontos et al.[34] evaluated 236 concussed patients, of which one third were characterized as having a vestibular or ocular profile. Dizziness is the second most commonly reported symptom (50-84.1%) in concussed patients[5,7,30-33,35] and balance impairments are reported in 40-80% of concussed patients,[5,31,42] both of which are believed to stem from a disruption of the vestibular system. The vestibular system gives a subjective sense of motion and orientation by detecting motion of the head in space. It detects angular and linear head acceleration, gravitational forces, and head tilt and coordinates compensatory eye and head movements, and leg and spine musculature to maintain gaze stabilization, posture and balance.[26-28] All of which occur during the multiplanar, dynamic movements an athlete goes through during sport. The Gapski-Goodman Test

(GGT) is a standardized exertion assessment with both an aerobic and dynamic component used to determine athlete RTP readiness following a SRC. The aerobic component includes high-intensity intervals with gradual hill climbs on a stationary bike and the dynamic component includes various plyometric activities (i.e. lateral hurdle jumps, lateral box jumps, burpees, jumping 180° rotations). Self-reported symptom provocation is recorded throughout the assessment and the GGT is terminated at the first sign/report of symptom exacerbation.[20] No rational for exercises choosen is given and passing the GGT assessment is dependnt on self reported symptoms which are known to bia. Marshall et al.[20] evaluated 759 athletes during their RTP progression which included being asymptomatic, returning to the classroom, successful BCTT performance, successful participation in two non-contact practices and successful GGT before full RTP was given. They found that while 100% of athletes completed the BCTT with no symptom exacerbation, 14.6% went on to experience symptom provocation during the GGT. This demonstrates that aerobic exercise alone is not sufficient, and the addition of standardized, dynamic tests could be a possible clinical approach for determining the RTP in athletes recovering from a SRC.

1.4 Problem Statement

A concussion is a heterogeneous injury that requires a multifaceted approach, including neurocognitive, ocular, vestibular, symptom, and exertion assessments,[59] when diagnosing, treating and determining RTP readiness. There is currently no 'gold standard' for the determination of RTP readiness after a SRC, it is primarily based on expert recommendations.[1,12] Current RTP exertion protocols do not provide rational for exercise type, intensity, or duration and are reliant on the subjective recall of symptoms from athletes, which is prone to bias as some concussion-related symptoms may be related to other non-concussion factors and/or athletes may underreport symptoms.[1,8,17,18,22] VOMS is a brief assessment used to screen for vestibular and ocular motor impairments.[5] Studies have shown that VOMS scores increase following bouts of structured exercises including sprints, push-ups and sit-ups,[29] but not during treadmill running.[66] Strictly aerobic exertion protocols, like those performed on a treadmill, do not accurately replicate the dynamic movements that occur during sports. [67,68] These multiplanar, dynamic movements require athletes to use synchronized head and body movements which often provoke an impaired vestibular system in a concussed person.[25-28] Popovich et al.[69] evaluated symptom provocation of concussed athletes following both a basic cardiovascular exercise protocol followed by a dynamic exercise protocol. Of the 66.2% of athletes who reported symptom provocation, 55.6% did not have symptom provocation until the dynamic exercise protocol, with dizziness being the most common symptom provoked (48.5%). EXiT is a standardized RTP exertion assessment with objective measures and an exercise prescription based on guidelines from the ACSM.[36] It incorporates aerobic, multiplanar dynamic, and functional movements that work to challenge all potentially affected systems of an athlete at medical clearance from a SRC. However, the reliability between clinicians (inter-rater reliability) of EXiT is currently unknown.

1.5 Purpose Statement

The purpose of this study is to determine the interrater reliability (IRR) for the administration of the EXiT in healthy, non-concussed athletes and to determine the level of systematic bias between raters' scores.

1.6 Specific Aims and Hypothesis

1. Examine inter-rater reliability (IRR) of the EXiT between two raters recording errors during dynamic circuit, ball toss and agility cone tasks and time to completion (trials 1 and 2) during agility cone tasks among healthy participants 19-33 years of age.
    a. Hypothesis: Given that both raters are trained Certified Athletic Trainers, we expect the raters will have a moderate to high level of agreement.
2. Establish the level of systematic bias between raters on recording errors and time to completion.
    a. Hypothesis: Given that both raters are trained Certified Athletic Trainers, we expect there to be little systematic bias between raters.

1.7 Study Significance

Many healthcare assessments rely on the interpretation of clinicians, although this introduces a potential source of error as multiple clinicians can interpret things differently. Healthcare assessments require a level training so that the amount of variability in how each clinician views or interprets the results in reduced. The extent or level of agreement among clinicians (raters) is IRR.[70] As a new clinical assessment, the level of agreement between raters on the EXiT is currently unknown. The reliability of a health care assessment is important as the results of any one assessment should be consistent across different raters so that an informed clinical decision can be made. This study is the first step in assessing the reliable utilization of the EXiT in the clinical setting.

2.0 Methods

2.1 Experimental Design

This study utilized a within subjects, repeated measures design with 15 healthy athletes over two research visits. Two raters recorded participants' errors and time to completion on the Dynamic Exertion Test (EXiT) tasks at each visit to examine interrater reliability (IRR) for EXiT. Each participant had a total of four scores for each EXiT task, one from each rater for two visits.

2.1.1 Independent Variables

Independent variables for this study included both rater 1 and rater 2 scoring participants and the EXiT assessment with the different types of exertional exercises (treadmill running, dynamic circuit, ball toss and agility cone tasks).

2.1.2 Dependent Variables

Dependent variables for this study included each participant's time to completion and errors during the EXiT tasks.

2.2 Participants

Participants were recruited from the University of Pittsburgh and surrounding community. Each potential participant was screened either in person, or a phone interview by trained personnel, or electronically via “Pitt + Me” web services. Screening procedures were conducted by referring to a screening script (see Appendix A). Eligible participants were invited to complete assessments at the Neuromuscular Research Laboratory (NMRL) and received additional information about study methods before signing informed consent. All eligible participants were screened for eligibility by the American College of Sports Medicine (ACSM) pre-participation screening algorithm (Physical Activity Readiness Questionnaire [PAR-Q+]) to ensure participants do not endorse cardiovascular risk factors from conducting moderate to vigorous exercise. Potential participants were screened either in person or during a phone interview by trained personnel prior to, or the day of their first visit. This study was approved by the Institutional Review Board at the University of Pittsburgh prior to implementation of all research procedures.

2.2.1 Inclusion Criteria

Individuals were between the ages of 14 - 35 and considered physically active. Physically active was be defined according to the ACSM guidelines for maintaining aerobic activity: thirty minutes of moderate-intensity exercise five days per week or twenty minutes of vigorous exercise three days per week.[36]

2.2.2 Exclusion Criteria

The following factors are known to influence performance or alter reporting behavior and thus if any one exclusion criterion was met, the individual was unable to participate in the study. If the individual had suffered a concussion within the last 6 months, had more than 2 previous concussions, if they have a history of brain surgery or Traumatic Brain Injury (TBI) (based on Glasgow Coma Scale of <13) or have a history of neurological disorder (seizure disorder, epilepsy, brain tumors, malformations) they were excluded. Potential participants were excluded if they had a current history of preexisting vestibular disorder, been previous diagnosis of ocular motor condition, or a cardiac, peripheral, or cerebrovascular disease (type 1 or 2 diabetes, renal disease). If they are currently taking antidepressant, anticoagulant, beta-blockers, and/or anticonvulsant prescription medications, or if they are pregnant. Participants were excluded if incapable of treadmill running up to 8.5 mph and 7.0 mph for males and females, respectively, experienced chest pain or shortness of breath while at rest or with mild exertion or lose balance because of dizziness or have lost consciousness from exertion. Participants were also excluded if they were diagnosed with or taking medication for a chronic medical condition, currently have a mental or physical impairment exacerbated by physical activity, leading to the inability to complete 30 minutes of moderate to vigorous exercise, or have been told by a doctor to only conduct physical activity under medical supervision.

2.3 Power Analysis

This study is part of a larger study designed to overview a new Dynamic Exertion Test (EXiT) (IRB_PRO19060627). An alpha level was set at 0.05 with an effect size of 0.4, one-tailed test. To achieve 80% power 100 healthy participants and 40 concussed participants were needed. In anticipation for 20% attrition rate 120 healthy and 50 concussed participants was the recruitment goal.

We used a subset of 15 participants from the healthy control group (n=92). Every other participant enrolled after the 10th participant was used to assess the IRR of errors and time to completion of the EXiT tasks between two raters.

2.4 Instrumentation

2.4.1 Anthropometrics

Research personal collected participants bodyweight measurements (bodyweight [lbs.] via floor scale and height [cm] via wall mounted tape measure) to determine body mass index (BMI [lbs/cm^2]). Blood pressure (BP) was measured prior to and following exertion protocols by a trained clinician or research staff member. Heart rate (HR) was measured prior to, following and throughout exertion protocols. All participants were asked to wear a noninvasive HR monitor (Equivital or Polar strap) to capture HR and accelerometer information in the X, Y, and Z directions during the exertion protocols. During pre- and post-exertion measures resting HR and

BP were taken after a 5-min resting period with participants seated in a chair with their back supported and feet on the floor.

2.4.2 Physical Activity Readiness Questionnaire (PAR-Q)

The PAR-Q+ is the ACSM's formal screening to safely conduct submaximal exertion, it screens for diagnoses of a cardiac, peripheral, or cerebrovascular disease. Items include a previous diagnosis of heart condition or high blood pressure, shortness of breath or pain in chest at rest or with activities of daily living, current joint, bone, or soft tissue issues that could be worsened with exertion, and instruction by a doctor to only conduct physical activity under medical supervision.[36] (See Appendix B)

2.4.3 The Generalized Anxiety Disorder-7 item (GAD-7)

The GAD-7 is 7-item self-report questionnaire for anxiety. Participants rate the extent to which the individual is bothered by pre-specified problems on a 0-3 Likert scale (0 'not at all' to 3 'nearly every day'). It takes less than 5 minutes to complete.[71] (See Appendix B)

2.4.4 Patient Health Questionnaire-9 item (PHQ-9)

The PHQ-9 is a 9-item self-report questionnaire for depression. Participants rate the extent to which the individual is bothered by pre-specified problems within the previous 2 weeks on a 0-3 Likert scale (0 'not at all' to 3 'nearly every day'). It takes less than 5 minutes to complete.[72] (See Appendix B)

2.4.5 Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) & Post-Concussion Symptom Scale (PCSS)

The ImPACT is a computerized test used to assess the neurocognitive function of patients who are suspected to have a concussion. It includes a demographic questionnaire (relevant education, sports participation, and personal medical history), the PCSS, an injury evaluation form, and a 20-minute neurocognitive test. The neurocognitive section includes six tests the result in 4 different composite scores: verbal memory, visual memory, visual motor speed, and reaction time. The PCSS integrated into the ImPACT test contains 22 self-reported concussion related symptoms (headache, nausea, dizziness, trouble sleeping, etc.). Participants rate their symptoms on a scale of 0 (no symptom) to 6 (severe symptom) and total scores can range from 0-132. The ImPACT test takes approximately 25 minutes to complete [5,17] and has shown good sensitivity (81.9%) and good specificity (89.4%),[45] with moderate to good test-retest reliability (ICC = 0.737-0.91).[44,73] (See Appendix C)

2.4.6 Modified Balance Error Scoring System (mBESS)

The mBESS, which is a standardized test of balance and takes 5 minutes to complete. The test consists of three stances (double leg stance, single leg stance on the non-dominant leg, and tandem stance in a heel-to-toe fashion with the participant’s non-dominant foot behind the dominant foot) while the participant's hands are placed on their hips. Stances are performed on a firm surface with eyes closed. Each trial is timed for 20 seconds and errors are totaled. Errors include eyes opening, hands lifting off the hips, stepping/stumbling out of position, lifting forefoot or heel, abducting the hips by more than 30 degrees or failing to return to the test position within 5 seconds following an error.[74] (See Appendix C)

2.4.7 Dynamic Exertional Testing (EXiT) Protocol

EXiT is a 30-min physical evaluation of readiness for RTP that includes uniplanar/aerobic and multiplanar/dynamic components. The uniplanar/aerobic component is a treadmill protocol designed to achieve 70-89% of heart rate reserve, or moderate to vigorous intensity according to the ACSM.[36] Participants completed a 2-minute warm-up of steady-state running at a "low" speed and then complete 30 second intervals of high and low (1:1 ratio) for 10 minutes. The multiplanar/dynamic component includes coordinated head-body movements, functional agility and dual-task movements. Components of EXiT were timed, via a stop watch to two decimal points, and errors are recorded throughout on a standardized scoring sheet (See Appendix C). Subjects report on a Likert scale ranging from 0-10 (0=no symptoms, 10=severe symptoms) for headache (HA), dizziness (DZ) and nausea (NA), and rating of perceived exertion (RPE) on a Borg scale[75] ranging from 6 to 20 before, throughout, and after completing EXiT.

2.4.7.1 Aerobic Component

The treadmill running protocol alternated between moderate (64-76% of HR_{max}) and vigorous (77-95% HR_{max}) HR ranges to provide a brief screening of the autonomic nervous system.[76,77] The 90th percentile of cardiorespiratory fitness normative data (measured in mlO_2/kg/min) and ACSM's running equation was used to design a treadmill running protocol with a 1:1 work: rest ratio in which females alternate between 7.2 km/h (4.5 mph; 3.14 METs) and 11.27 km/h (7.0 m/h, 6.36 METs), and males alternate between 8.85 km/h (5.5 mph; 5.21 METs) and 13.67 km/h

(8.5 mph, 7.5 METs). Participants completed a 2-minute warm up (Male: 5.5 mph, Female: 4.5 mph), followed by 30-second intervals of fast and slow running speeds (Male: 8.5/5.5 mph; Female: 7.0/4.5 mph) for 10 minutes. Symptoms and RPE were recorded prior to and following the warm-up, and after completing the 5th and 10th intervals. Participants were instructed to use support handles as necessary to maintain safety, but that excessive pulling for 10 or more seconds or additional rest periods for greater than 10 seconds were counted as errors.

2.4.7.2 Dynamic Movement Component

Within 60 seconds of completing the aerobic component, participants completed 2 functional movement tasks *(Dynamic Circuit* and *Ball Toss*) and 5 agility cone tasks (*Box Drill Shuffle, Box Drill Carioca, Zigzag, Pro Agility, and Arrow Agility)*. After each task, participants had 30 seconds to report symptoms, rating of perceived exertion (RPE), and rest. Symptoms, RPE, HR and errors were recorded for all tasks by the administer. A full description with images of each dynamic component is available in Appendix C.

Dynamic Circuit: Squat jumps, side-to-side pushups, and ball rotations with a 30-second rest period for 3 consecutive cycles. Squat jumps were performed by participants squatting to 90° and jump straight up into the air. Each squat and jump was one repetition. Side-to-side pushups were performed by participants performing a pushup, walking their hands over to the left, doing a pushup, walking hand back to the midline, doing a pushup, walking hands to the right, pushup, and walking hands back to the midline, pushup. Each pushup with one repetition. Ball rotations were performed with participants in a standing position holding a basketball in both hands at arms-length. They rotated their upper body 180° side to side, keeping feet stationary, while keeping their eyes on the basketball (a full rotation from left to right and back was considered one repetition). Participants completed 10 repetitions of each exercise in synchronization with a metronome (25 beat/min) and were permitted 10 seconds to transition between exercises. Errors included improper form (not reaching 90° knee bend during squat jumps, not reaching 90° elbow bend during pushups or letting knees bend touching the ground) or inability to maintain metronome pace during squat, pushup, or ball rotation exercises.

Ball Toss: Participants stood with their backs turn to the administrator and 2.5 meters away. After the administrator called 'left', or 'right', the participant jumped and rotated 180° in the specified direction, caught a basketball tossed by the administrator, and tossed back before returning to the starting position for the next repetition. This was conducted for 10 repetitions (5 jumps left followed by 5 jumps to the right) and after a 30-second rest, a second round was performed whereby administrator called direction (left or right) or 'Go' (Distractor-no response/jump) in a random sequence (5 jumps left, 5 jumps right, and 2 distractors). A jump-turn in the wrong direction, inability to catch or toss ball back to administrator, or a jump (foot leaving the ground) committed after a 'Go' call were counted as errors.

Participants completed two trials of each agility cone task with a 30 second rest between trials (except Pro Agility – 15 second rest). Six agility cones (10cm in height) were placed in a rectangle pattern (2 rows with 3 cones each) 2.5 meters apart from each other. Instances in which participants kicked a cone off the original placement, mis-navigated a cone, or did not hand-touch a cone when instructed to do so were counted as errors. Instructions and demonstrations for each task were provided during the rest periods between tasks. All tasks begin with a "3, 2, 1, GO" count. After each task, participants had 30 seconds to report symptoms, rating of perceived exertion (RPE), and rest. Time to completion (measured with hand timer by administrator), errors, symptoms, HR and RPE were recorded by the administrator for all agility tasks.

Box Drill Shuffle: Using 4 of the 6 cones in 2.5m X 2.5m square, participants began at a "start" cone then sprinted forward to the first cone, side shuffled to the second cone, backpedaled to the third cone, and side shuffled to the "start" cone, making a square. After completing 2 "laps", participants immediately repeated this pattern in the opposite direction (4 total "laps"), rested for 30 seconds and repeated a second trial.

Box Drill Carioca: Using the same 4 cones as above, participants began at a "start" cone then sprinted forward to the first cone, carioca diagonally backwards to the third cone, sprinted forward to the second cone and carioca backwards diagonally to the "start" cone, making a figure eight. After completing 2 "laps", participants rested for 30 seconds and repeated a second trial.

Zigzag: Using all 6 cones, participants began at a "start" cone on the short end of the rectangle. Participants side shuffled to the left, touched the cone, and side shuffled diagonally up and to the right cone and touched the cone, and repeated this action for the remaining cones. After reaching the final cone, participants kept their body facing the same direction and completed the pattern in reverse order, touching every cone (starting with side-shuffle to the right), repeating until they returned to "start" cone. Participants completed 2 "laps", rested for 30 seconds and repeated a second trial.

Pro Agility: Using 3 cones on the long end of the rectangle, participants began at a "start" cone in the middle with a cone to their left and right. When cued, they turned right, sprinted to touch the right cone (2.5m), turned and sprinted to the touch the far left cone (5m), and turned and sprinted to touch each end cone one additional time (5m each) before sprinting through (no touch) the "start" cone (in the middle). Participants rested for 15 seconds before repeating a second trial, beginning to the left.

Arrow Agility: Using the same cones and same "start" cone position from *Pro Agility,* the administer presented a card with a block on the left or right side that corresponded to each end cone. The participant sprinted and touched the corresponding cone and returned to the "start" cone as quickly as possible as the administer presented the next card. This was a series of 16 cards (8 left, 8 right) presented in a randomized order (this randomized order was kept the same for each participant). Once the participant completed all 16 cards, they rested of 30 seconds. The participant then repeated the same drill, but the cards have arrows to indicate which cone to sprint and touch, regardless of the spatial location (left or right) on the card. A series of 16 cards were randomly presented, the cards include congruent (box-left/arrow-left and box-right/arrow-right) and incongruent (box-left/arrow-right and box-right/arrow-left) combinations that are each presented with 4 trials.

2.5 Procedures

All testing procedures were completed at the Neuromuscular Research laboratory (NMRL). Each research visit took approximately 90 minutes and participants completed 2 visits with 3-21 days in between visits. Prior to any involvement in the study, screening procedures and written consent and/or parental consent with child assent was obtained for all participants. Participants were further instructed to a) avoid ingesting food, alcohol, or caffeine or tobacco products within 2 hours of assessment; b) avoid vigorous exercise the day prior to and day of assessment; c) wear clothing and footwear to permit athletic movements; and d) drink plenty of fluids the 24-hour period before assessment.

Participants were asked general medical history, demographics, concussion history, and mood information via the GAD-7 and PHQ-9. Participants completed the ImPACT, VOMS, and mBESS with a research team member trained in the assessment's procedures. Each participants' resting BP and HR were collected after a 5-minute rest period, in a seated position with feet place flat on the floor and the back and arms supported, prior to and following the EXiT protocol. The EXiT protocol was administered by the same research team member (rater 1) for each participant. For the IRR, every other enrolled participant after the 10^{th} participant was also scored by a second research team member (rater 2) simultaneously with rater 1 at both visits until data was collected for a total of 15 participants, this was strictly systematic and was decided a priori. The two team members (rater 1 and rater 2) did not discuss or share their individual scores of the participants with one another and a separate research team member entered the scores into an electronic data bank.

All participants were monitored for adverse symptoms/events (i.e., excessive dizziness, respiratory distress) during their involvement in all assessments. If a participant adversely responded to assessments, they were removed from the study and referred to additional medical and clinical care. All procedures were in accordance with the declaration of Helsinki[78] and approved by the University of Pittsburgh Institutional Review Board.

2.6 Data Reduction

All error scores were converted from continuous numerical data to binary, categorical data before data analysis was completed. If no errors were committed a score of 0 was assigned, if any number of errors (≥1) were committed, a score of 1 was assigned.

2.7 Data Analysis

Descriptive statistics (mean, standard deviation, median, interquartile range, proportions) as appropriate were calculated for all variables. For continuous outcome variables interrater reliability (IRR) was calculated using intraclass coefficients (ICC 2,1), and 95% confidence intervals (CI). For categorical outcome variables IRR was calculated using Kappa Coefficient and 95% CI.[79,80]

Difference in ratings between the two raters were measured using paired t-tests for continuous variables and McNemar Tests for categorical variables. Statistical significance was set a priori at alpha = 0.05, two-sided. Statistical analysis was conducted using SPSS (IBM SPSS Statistics for Windows, Version 26.0).

3.0 Results

3.1 Demographic Information

One hundred percent (n=15) of the participants who were enrolled were analyzed during their first visit but only 80% (n=12) of those enrolled returned for their second visit and were analyzed. Frequencies or mean and standard deviations (SD) for all demographic variables are reported in Table 1. The average age of participants was 23.67 ± 4.22 years old (range 19-33 years old), with 66.7% male gender, and 86.66% participating in full-contact sports. A total of 3 (20%) participants had sustained a concussion in the past, and only 1 (6.6%) of which had a history of more than one concussion (Table 2). No participants had a medical history of migraines, attention-deficit or hyperactivity disorders, or a learning disability (Table 2). Mean and SD for all baseline assessments (ImPACT, VOMS, mBESS, GAD-7, and PHQ-9) are reported in Table 3, scores between both visits are statistically similar.

Table 1

Table 1. Frequency (Percentage), or Mean and Standard Deviation (M ± SD) of Demographic Variables for Participants (n=15)

Variable	Mean ± SD	Frequency (Percentage)
Gender		
Female	-	5 (33.3%)
Male	-	10 (66.7%)
Age (years)	23.67 ± 4.22	-
Height (cm)	173.63 ± 8.86	-
Weight (kg)	77.75 ± 15.87	-
Body Mass Index (kg/cm^2)	25.57 ± 3.82	-
Predicted Maximum Heart Rate (beats/min)	196.22 ± 4.22	-
Sport		
Basketball	-	4 (14.8%)
Football	-	4 (14.8%)
Soccer	-	3 (11.1%)
Lacrosse	-	1 (3.7%)
Wrestling	-	1 (3.7%)
Volleyball	-	1 (3.7%)
Gymnastics	-	1 (3.7%
Sport Category[1]		
Full Contact/Collision	-	13 (48.1%)
Limited Contact	-	1 (3.7%)
Non-Contact	-	1 (3.7%)

[1] Sport Classification Endorsed by American Academy of Pediatrics[81]

Table 2

Table 2. Frequency (Percentage of Medical History Variables for Participants (n=15)

Variables	Frequency (Percentage)
Clinical Factors	
Migraine/Headache History	0
Attention-Deficit/ Hyperactivity Disorder	0
Learning Disability	0
Number of Previous Concussions	
0	12 (44.4%)
1	2 (7.4%)
2	1 (3.7%)

Table 3

Table 3. Mean and Standard Deviation of Baseline Clinical Assessment Scores Between Participants' First (N=15) and Second (N=12) Visits[1]

Outcome	Visit One (n=15) Mean ± SD	Visit 2 (n=12) Mean ± SD
Immediate Post-Concussion Assessment and Cognitive Testing		
Verbal Memory	90.73 ± 6.32	92.33 ± 7.09
Visual Memory	86.6 ± 7.60	84.67 ± 12.15
Motor Processing Speed	44.15 ± 5.70	43.8 ±7.93
Reaction Time	0.56 ± 0.06	0.055 ± 0.04
Impulse Control	5.53 ± 3.66	4.91 ± 1.98
Symptom Severity Score	2.33 ± 2.55	2.08 ± 2.94
Vestibular-Ocular Motor Screening		
Baseline Sx	0.2 ± 0.78	0
Smooth Pursuits Sx	0.2 ± 0.78	0
Horizontal Saccades Sx	0.2 ± 0.78	0
Vertical Saccades Sx	0.2 ± 0.78	0
Convergence Sx	0.27 ± 0.8	0
NPC (cm)	3.10 ± 2.55	2.17 ± 1.54
Horizontal VOR Sx	0.27 ± 0.8	0
Vertical VOR Sx	0.2 ± 0.6	0
VMS	0.33 ± 0.9	0
Total Symptoms	1.87 ± 6.15	0
Modified Balance Error Scoring System Total	1.50 ± .905	1.75 ± 3.049
Generalized Anxiety Disorder- 7 item	2.07 ± 2.55	1.58 ± 2.84
Patient Health Questionnaire-9 item	1.27 ± 1.67	1.75 ± 2.22

[1]Three-21 days between visits; average of 9.58 ± 5.09 days.
Abbreviations: Symptoms (Sx), Vestibular-Ocular Reflex (VOR), Visual Motion Sensitivity (VMS), Near Point Convergence (NPC)

3.2 Interrater Reliability

Good to excellent IRR was demonstrated for time to completion for all EXiT tasks, with ICC [2,1] ranging from 0.759 to 0.999 (Table 4). The highest scores were from visit 1 Zigzag trail 1, visit 1 Arrow Agility trail 2, and visit 2 Zigzag trial 2 (0.998 [95% CI, 0.994-0.990], 0.999 [95% CI, 0.997-1.0], and 0.998 [95% CI, 0.993-0.999] respectively). The lowest scores were from visit 1 Pro Agility trial 1 and 2, and visit 2 Box Drill Carioca trial 2 (0.873 [95% CI, 0.671-0.955], 0.899 [95% CI, 0.640-0.968], and 0.759 [95% CI, 0.314-.926] respectively).

Poor to excellent IRR was demonstrated for the number of errors committed on each task, with Kappa coefficient values ranging from 0.324 (minimal level of agreement) to 1 (almost perfect agreement) (Table 5). Visit 1 and 2 Dynamic Circuit, visit 1 Ball Toss and visit 1 Pro Agility all had an overserved percent agreement of 100%. The lowest scores were from visit 1 and 2 Zigzag, visit 1 and 2 Arrow Agility, and visit 2 Dox Drill Shuffle (0.324 [95% CI, -0.152-0.800], 0.471 [95% CI, -0.035-0.977], 0.375 [95% CI, -0.034-0.784], 0.437 [96% CI, -0.020-0.894], and 0.429 [95% CI, -0.165-1.023] respectively). Zigzag and Arrow Agility also had the lowest overserved percent agreement (66.66-75% and 73.33-75% respectively). Kappa Coefficients could not be calculated for visit 2 Ball Toss or visit 2 Pro Agility as all scores for one or more of the raters were not binary.

Of the 15 total participants, 12 (80%) returned for the second visit, with an average of 9.58 ± 5.09 days between the two visits. The test-retest reliability was not calculated for the subset of participants used in this study, as another study used the entire healthy participant population (n=92) to evaluate the intra-rater and test-retest reliability of EXiT tasks (STUDY19080194).

Table 4

Table 4. Mean, Standard Deviation, and Intraclass Correlation Coefficients for time to completion (two trials in seconds) between raters for two visits (visits one n=15, visit two n=12)

OUTCOME		RATER 1 Mean ± SD	RATER 2 Mean ± SD	ICC [2,1] (95% CI)	Sig. (p-value)
Visit 1					
Box Drill Shuffle	Trial 1	22.38 ± 3.01	22.34 ± 3.56	0.950 (.859-.983)	0.001
	Trial 2	21.61 ±2.84	21.38 ± 2.72	0.992 (.950-.998)	0.001
Box Drill Carioca	Trial 1	14.25 ± 1.73	14.22 ±1.76	0.969 (.909-.989)	0.001
	Trial 2	14 ± 1.57	13.85 ± 1.83	0.944 (.844-.981)	0.001
Zigzag	Trial 1	29.73 ± 4.46	29.78 ± 4.34	0.998 (.994-.99)	0.001
	Trial 2	30.02 ± 4.32	29.93 ± 4.28	0.993 (.981-.998)	0.001
Pro Agility	Trial 1	8.33 ± 1.00	8.06 ± 1.07	0.899 (.640-.968)	0.001
	Trial 2	8.13 ± 0.94	8.01 ± 0.94	0.873 (.671-.955)	0.001
Arrow Agility	Trial 1	40.16 ± 5.62	39.98 ± 5.58	0.997 (.990-.999)	0.001
	Trial 2	42.96 ± 4.79	42.85 ± 4.74	0.999 (.997-1.0)	0.001
Visit 2					
Box Drill Shuffle	Trial 1	20.35 ± 2.10	20.20 ± 2.01	0.986 (.951-.996)	0.001
	Trial 2	20.66 ± 2.27	20.34 ± 2.24	0.980 (.818-.995)	0.001
Box Drill Carioca	Trial 1	13.38 ± 1.42	13.32 ± 1.36	0.968 (.890-.991)	0.001
	Trial 2	13.62 ± 1.83	12.97 ± 1.37	0.759 (.314-.926)	0.001
Zigzag	Trial 1	28.53 ± 4.68	28.59 ± 4.38	0.990 (.966-.997)	0.001
	Trial 2	30.02 ± 5.28	29.90 ± 5.39	0.998 (.993-.999)	0.001
Pro Agility	Trial 1	8.53 ± 1.77	8.40 ± 1.72	0.976 (.923-.993)	0.001
	Trial 2	8.19 ± 1.27	8.24 ± 1.14	0.949 (.834-.985)	0.001
Arrow Agility	Trial 1	39.77 ± 5.18	40.60 ± 5	0.907 (.717-.972)	0.001
	Trial 2	41.68 ± 5.36	41.09 ± 5.36	0.954 (.855-.987)	0.001

Table 5

Table 5. Kappa Coefficients for task errors between raters for two visits (first visit n=15, second visit n=12)

Outcome	Kappa Coefficient (95% CI)	Sig. (p-value)	Observed Percent Agreement
Visit 1			
Dynamic Circuit	1	**0.001**	100%
Ball Toss	1	**0.001**	100%
Box Drill Shuffle	.815 (.470-1.160)	**0.001**	93.33%
Box Drill Carioca	.842 (.546-1.138)	**0.001**	93.33%
Zigzag	.324 (-.152-.800)	0.205	66.66%
Pro Agility	1	**0.001**	100%
Arrow Agility	.375 (-.034-.784)	0.063	73.33%
Visit 2			
Dynamic Circuit	1	**0.001**	100%
Ball Toss	-	-	100%
Box Drill Shuffle	.429 (-.165-1.023)	0.070	83.33%
Box Drill Carioca	.636 (.207- 1.065)	0.018	83.33%
Zigzag	.471 (-.035-.977)	0.098	75%
Pro Agility	-	-	91.66%
Arrow Agility	.437 (-.020-.894)	0.067	75%

3.3 Systematic Bias Between Raters

The mean difference between raters' time to completion scores were evaluated to assess for any systematic bias between raters scoring. There were no statistically significant differences between raters scores on 15/20 (75%) task trials (Table 6). However, there were differences in visit 1 and 2 Box Drill Shuffle trail 2, visit 1 Pro Agility trial 1, visit 1 Arrow Agility trial 2, and visit 2 Box Drill Carioca trial 2 ($p < .007$, $p < .006$, $p < .020$, $p < .020$, and $p < .048$, respectively).

McNemar Tests was used to assess for systematic bias between rater's error scores (Table 7). There were no statistically significant differences between raters on 8/14 (57%) task. However, there were differences in Box Drill Shuffle (0.500) and Box Drill Carioca (0.500) on visit 2 and Arrow Agility on visit 1 and 2 (0.125 and 0.250 respectively). Arrow Agility had the largest difference between raters scores. At visit 1 rater 1 gave 2 /15 (13.33%) participants errors and rater 2 gave 6/15 (40%) participants errors. On visit 2 rater 1 gave 2/12 (16.66%) participants errors and rater 2 gave 5/12 (41.66%) participants errors. Like the Kappa Coefficients, McNemar Test could not be calculated for visit 2 Ball Toss and visit 2 Pro Agility as all scores for one or more of the raters were not binary.

Table 6

Table 6. Mean difference (rater 1- rater 2), standard deviations, and CI between raters on time to completion

OUTCOME		RATER 1 (Mean ± SD)	RATER 2 (Mean ± SD)	Mean Difference ± SD	95% CI	Sig. (p-value)
Visit 1 (n=15)						
Box Drill Shuffle	Trial 1	22.38 ± 3.01	22.34 ± 3.56	.041 ± 1.073	(-.553-.635)	0.884
	Trial 2	21.61 ±2.84	21.38 ± 2.72	.229 ± .282	(.073-.385)	**0.007**
Box Drill Carioca	Trial 1	14.25 ± 1.73	14.22 ±1.76	.030 ± .452	(-.221-.28)	0.801
	Trial 2	14 ± 1.57	13.85 ± 1.83	.119 ± .579	(-.202-.439)	0.441
Zigzag	Trial 1	29.73 ± 4.46	29.78 ± 4.34	-.044 ± .295	(-.207-.119)	0.573
	Trial 2	30.02 ± 4.32	29.93 ± 4.28	.083 ± .500	(-.194-.36)	0.533
Pro Agility	Trial 1	8.33 ± 1.00	8.06 ± 1.07	.271 ± .400	(.103-.492)	**0.020**
	Trial 2	8.13 ± 0.94	8.01 ± 0.94	.117 ± .477	(-.147-.382)	0.357
Arrow Agility	Trial 1	40.16 ± 5.62	39.98 ± 5.58	.175 ±.443	(-.07-.42)	0.147
	Trial 2	42.96 ± 4.79	42.85 ± 4.74	.0133 ± .152	(.019-.188)	**0.020**
Visit 2 (n=12)						
Box Drill Shuffle	Trial 1	20.35 ± 2.10	20.20 ± 2.01	.143 ± .332	(-.068-.354)	0.163
	Trial 2	20.66 ± 2.27	20.34 ± 2.24	.322 ± .329	(.113 -.530)	**0.006**
Box Drill Carioca	Trial 1	13.38 ± 1.42	13.32 ± 1.36	.159 ± .327	(-.049-.367)	0.120
	Trial 2	13.62 ± 1.83	12.97 ± 1.37	.645 ±1.000	(.007-1.28)	**0.048**
Zigzag	Trial 1	28.53 ± 4.68	28.59 ± 4.38	-.067 ± .660	(-.49-.3.57)	0.735
	Trial 2	30.02 ± 5.28	29.90 ± 5.39	.126 ± .335	(-.087-.339)	0.220
Pro Agility	Trial 1	8.53 ± 1.77	8.40 ± 1.72	.131 ± .373	(-.106-.368)	0.250
	Trial 2	8.19 ± 1.27	8.24 ± 1.14	-.055 ± .399	(-.308-.198)	0.642
Arrow Agility	Trial 1	39.77 ± 5.18	40.60 ± 5	-.835 ± 2.105	(-2.172-.502)	0.197
	Trial 2	41.68 ± 5.36	41.09 ± 5.36	.581 ± 1.579	(-.423-1.58)	0.229

Table 7

Table 7. McNemar Test, frequencies, and percentages for task errors (yes scores) between raters

Outcome	Rater 1	Rater 2	Sig. (p-value)
Visit 1 (n=15)			
Dynamic Circuit	2/15 (13.3%)	2/15 (13.3%)	1.000
Ball Toss	1/15 (6.66%)	1/15 (6.66%)	1.000
Box Drill Shuffle	4/15 (26.66%)	3/15 (20%)	1.000
Box Drill Carioca	4/15 (26.66%)	5/15 (33.33%)	1.000
Zigzag	6/15 (40%)	7/15 (46.66%)	1.000
Pro Agility	2/15 (13.33%)	2/15 (13.33%)	1.000
Arrow Agility	2/15 (13.33%)	6/15 (40%)	0.125
Visit 2 (n=12)			
Dynamic Circuit	1/12 (8.33%)	1/12 (8.33%)	1.000
Ball Toss	0/12 (0%)	0/12 (0%)	-
Box Drill Shuffle	1/12 (8.33%)	3/12 (25%)	0.500
Box Drill Carioca	5/12 (41.66%)	3/12 (25%)	0.500
Zigzag	5/12 (41.66%)	4/12 (33.33%)	1.000
Pro Agility	0/12 (8.33%)	1/12 (8.33%)	-
Arrow Agility	2/12 (16.66%)	5/12 (41.66%)	0.250

4.0 Discussion

The purpose of this study was to determine the IRR of the EXiT between two raters assessing healthy, non-concussed athletes, and evaluate the level of systematic bias between raters. Specifically, raters' time to completion scores and errors given to participants on each of the tasks in the dynamic/multiplanar portion of EXiT (Dynamic Circuit, Ball Toss [errors only], Box Drill Shuffle, Box Drill Carioca, Zigzag, Pro Agility, and Arrow Agility [time and errors]) were evaluated. EXiT is a new assessment used to determine RTP readiness for athletes at medical clearance following a SRC. Many healthcare assessments rely on the interpretation of clinicians. The extent or level of agreement among clinicians (raters) is IRR.[70] As a new clinical assessment, the level of agreement between raters on the EXiT is currently unknown. The reliability of a health care assessment is important as the results of any one assessment should be consistent across different raters so that an informed clinical decision can be made. It was hypothesized that raters for this study would have a moderate to high level of agreement and that there would be no systematic bias between raters, as both raters are trained Certified Athletic Trainers and all participants were healthy. This hypothesis was supported by the results of this study as time to completion had good agreement between raters and errors had good agreement between raters for the majority of EXIT tasks.

Time to completion was recorded via a stopwatch app on a smart phone for both raters. Both trials for all agility cone tasks (Box Drill Shuffle, Box Drill Carioca, Zigzag, Pro Agility, and Arrow Agility) were timed. Timing began on the 'GO' of the '3, 2, 1, GO!' instruction given to the participants by rater 1 and stopped when the participants ran through the final cone. Good IRR was demonstrated for time to completion between the two raters and the raters' times were all within 0.030 to 0.835 ± 2.105 seconds of each other. Raters only had statistically different times on 4 tasks: Box Drill Shuffle (visit 1 and 2, trials 2), Box Drill Carioca (visit 2, trial 2), Pro Agility (visit 1, trial 1), and Arrow Agility (visit 1, trial 1). These differences seem to be random but could be due to the validity of the timing measurement in which raters need to be re-trained. It could also be due to a delayed reaction of rater 2, as rater 1 was always giving the 'GO' instruction and perhaps able to start their stopwatch quicker. Rater 2's time scores were slower than rater 1's scores on 16 of the 20 time points, including on each of the time points that were significantly different. Rater 2 only had faster times on Zigzag (visits 1 and 2, trial 1), Pro Agility (visit 2, trial 2) and Arrow Agility (visit 2, trial 1). Regardless of the reasoning, this bias needs to be eliminated and reliability recalculated for those tasks.

Each rater scored errors committed by participants based on predetermined rules for all tasks of the dynamic/multiplanar portion of EXiT. For the Dynamic Circuit (jump squats, side to side pushups, and ball rotations) errors included improper form (not reaching 90° knee bend during squats and not reaching 90° elbow bend or letting knees touch the ground during pushups) and the inability to maintain pace with the metronome during all exercises. Errors during Ball Toss included a jump-turn in the wrong direction, the inability to catch or toss the ball back to the rater, or a jump committed after a 'Go' call (distractor call). For the cone agility drills (Box Drill Shuffle, Box Drill Carioca, Zigzag, Pro Agility, and Arrow Agility) errors were instances when participants kicked/knocked a cone from its original placement, mis-navigated a cone, or did not hand-touch a cone when instructed to do so. Our data showed that error scores had overall good agreement between raters. The Dynamic Circuit, Ball Toss, and Pro Agility for both visits, and the Box Drill Shuffle and Box Drill Carioca at visit 2 all had 91.66-100% agreement, with the remaining tasks having 66.66-83.33% agreement. Zigzag at visit 1 had the lowest observed percent agreement at

66.66%, where rater 1 gave 6/15 (40%) participants errors and rater 2 gave 7/15 (46.66%) participants errors. However, Arrow Agility error scores (73.33% - 75% agreement) had the largest bias between raters' scores. During visit 1 rater 1 gave 2/15 (13.33%) participants errors but rater 2 gave 6/15 (40%) participants errors and during visit 2 rater 1 gave 2/12 (16.66%) participants errors while rater 2 gave 5/12 (41.66%) participants errors. This could be due to rater 1 being responsible for handling the cue cards used to direct participants during the Arrow Agility task, which involved holding cards up and removing the front card, placing it on a table in from of them, as soon as the participant moved in one direction or the other. This could have potentially caused rater 1 to miss some errors committed by participants, especially the hand-touch instruction, while rater 2 was able to observe the participants without having to also focus on the cue cards. This bias needs to be addressed and eliminated before reliability is determined for Arrow Agility.

4.1 Limitations and Future Research

This study has several limitations that should be addressed in future research. Human error is always a risk in clinical assessment tools and time to completion for each EXiT task was determined by hand time. However, the two raters in this study had good IRR and another study by Mann et al.[82] evaluated the reliability of electronic touch pad start with infrared beam stop against hand stopwatch time with both experienced and novice timers on collegiate athletes 40-yard dash times. They found no significant differences between the timing types ($p = 0.93$) or between experienced and novice timers (ICC > 0.987). Another area in which human error may play a role was in each raters' responsibilities and viewing position/perception during the EXiT testing. Rater 1 administered the EXiT assessment to every participant (gave instructions and demonstrations), while rater 2 only watched and scored. Rater 2 did not interact with participants and often observed from a different location then where rater 1 observed. This could be responsible for the random pattern of significant differences between raters' error and time scores on some tasks. Previous studies have evaluated the IRR of dynamic sport assessments using video recordings of participants, allowing all raters to have the same view/perception of each participant.[83-85] Future reliability research of EXiT should consider the use of video recordings.

Using video recording may also assist with another limitation present in this study, the use of only two raters to calculate IRR. If participants are video recorded, then multiple raters would be able to participate more easily. Raters, who are generally practicing health care professionals, could score the participants on their own time instead of having to work around each other's schedules. Future research should also include calculations for intra-rater reliability and retest reliability as these calculations were not done in the current study. This was because those calculations are to be included as part of the main study with the entire healthy participant population (n=92) (STUDY19080194). Additionally, the participant population of this study was small (n=15) and did not include adolescents. Future research should consider the use of a larger population with a wider age range.

Lastly, scoring errors committed during the EXiT is not well standardized. There were predetermined rules for what was considered an error, but raters only keep track of how many errors were committed by each participant for each task and no clinical cut off point is established yet. This data was originally going to be calculated as a continuous data, however, upon evaluation of the results the error scores were very skewed across all participants. Many participants had 0 errors, but some had as many of 19 errors on a single task. To simplify the statistical analysis the error scores were converted to binary scores, 0 for no errors committed or 1 for any number of errors committed. Longmuir et al.[85] evaluated the reliability of the Canadian Agility and Movement Skill Assessment (CAMSA) in children. They also used time to competition and an error scoring system as outcome variables, however, they gave participants a 0 if they committed any errors, indicating a failure of that task, or a 1 if they performed the task without errors, passed. Total points were added up at the end of the assessment and a total of 14 points was possible as there were 14 tasks they were scored on. Counting errors in this way made their data continuous and they were about to calculate ICCs for both time and errors. This error scoring system could be taken into consideration during future development of clinical cut off points for the EXiT error scoring system.

4.2 Study Significance

The current study builds upon research working to improve RTP assessments for concussions. It is the first step in evaluating the reliability of a new RTP assessment, the EXiT, which is important for any health care assessment as results should be consistent among different clinicians/raters so that an inform clinical decisions can be made. This study provides insight into the level of agreement between raters, the IRR, on the EXiT in healthy participants. We found that two separate raters can reliably determine the time to completion (ICC > 0.759) and errors (observed percent agreement > 66.66%). Both these variables are more objective than self-reported symptoms that other RTP protocols rely on. Even though these outcomes are subjective to human error, we found that the two raters did not differ significantly in how they scored time ($p > 0.250$) or errors ($p > 0.120$) for most tasks.

4.3 Conclusion

There is currently no 'gold standard' for the determination of RTP readiness after a SRC.[1,12] The most widely used RTP protocol is from the CISG and they recommend a progression through a graduated series of steps before full medical clearance for RTP is given.[1] However, exercise type, duration, and intensity of each stage is vaguely described, leaving highly variable approaches between administering clinicians[16], and progression through each step is reliant on the subjective recall of symptoms from athletes, which is prone to bias.[1,8,17,18,22] Submaximal exercise, while staying under symptom exacerbation threshold, is considered safe and potentially beneficial for concussed people,[1,10-14] because of this, exertion protocols are being developed to determine physiologic recovery and RTP readiness of concussed athletes.[19-21] However, strictly aerobic exertion protocols, like those performed on a treadmill, do not accurately replicate the dynamic movements that occur during sports [67,68] and RTP assessments that include both an aerobic and dynamic components need more objective outcome measures and a stronger rational for the exercises chosen.[20] The EXiT is a standardized RTP exertion assessment with objective outcome measures (time and errors), in addition to self-report symptoms. It incorporates aerobic, multiplanar dynamic, and functional movements, based on exercise prescription guidelines from the ACSM,[36] that work to challenge all potentially affected systems of an athlete at medical clearance from a SRC. As a new RTP assessment the reliability of EXiT is unknown. Our data show that the IRR for the EXiT outcomes (time to completion and errors committed) is good for the majority of tasks. This study is the first step in assessing the reliable utilization of the EXiT in the clinical setting.

Appendix A **: Phone Screening Script**

Hello **[NAME OF POTENTIAL PARTICIPANT-Control]**,

My name is **[NAME HERE]**, and I am a researcher at the University Of Pittsburgh School Of Medicine. Thank you for your interest in our study. If you are a under the age of 18 you will need a parent or legal guardian present to continue. This research will compare the similarities and differences between 2 types of physical activity among patients following a sport-related concussion. The assessment includes running on a treadmill or in an open 10-meter space. We will also ask (you/your child) to complete thinking, eye tracking, and mood tests, as well. If enrolled, the visit will take approximately 60 minutes to complete. Your/your child will be compensated up to $75 for participating. Are you interested in hearing more?

If yes, continue:

If no: thank you for your call.

To determine if you/your child are/is fully eligible to participate, I will need to ask some more questions to see if you are eligible. All responses are confidential, will be kept in a secure location, and discarded if you choose not to participate. Also, answering questions is voluntary and you may choose to stop at any time if you feel uncomfortable or for any other reason. Do I have your permission to ask these screening questions?

If No: Thank you very much for listening, have a good day

If Yes: These questions are similar to the standard health questions asked here at the UPMC Sports Medicine Concussion Program and American College of Sports Medicine.

____ ____________________

Staff Who Obtained Verbal Consent **Date / Time**

Adult/Parent: YES / NO Child: YES / NO

Inclusion	
Question	Response*

	Yes	No
Are you currently between the ages of 14 and 35?		
Prior to your injury, were you physically active as completing 30 minutes of moderate-intensity exercise 5 days per week or 20 minutes of vigorous exercise 3 days per week?		
*"Yes" responses meet inclusion criteria		

Was all inclusion criteria met? ☐ **Yes** ☐ **No**

Exclusion		
Question	Response*	
	Yes	No
Have you been diagnosed with a separate concussion in the past six months?		
Have you ever had brain surgery or been diagnosed with a traumatic brain injury or TBI (based on Glasgow Coma Score of <13)?		
Have you ever been diagnosed with a neurological or seizure disorder?		
Have you ever been diagnosed with a vestibular or balance disorder or impairment?		
Have you ever been diagnosed with an ocular motor condition?		
Are you taking any anticoagulant, beta-blocker, or anticonvulsant prescription medications?		
Are you capable of running up to a speed of: Male: 8.5 mph/ Female: 7.0 mph on a treadmill OR Running across a full-length football/soccer field in: Male: 25 seconds/ Female 30 seconds		
CV/Metabolic or Renal Disease Screening		
Have you been diagnosed with a cardiac, peripheral, or cerebrovascular disease, Type 1 or 2 Diabetes, or a renal disease?		
PAR-Q+ Questions		
Has your doctor ever said that you have a heart condition or high blood pressure?		
Do you feel pain in your chest or shortness of breath at rest, during your daily activities of living, OR when you do light to moderate exertion?		
Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months?		
Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?		
Are you currently taking prescribed medications for a chronic medical condition (i.e., diabetes)?		
Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by physical activity?		
Has your doctor ever said that you should only do medically supervised physical activity?		

Were any exclusion criteria met? ☐ **Yes** ☐ **No**

Is Subject eligible for study ☐ **Yes** ☐ **No**

If Ineligible: Your answers indicate you will ***not*** be eligible to participate in this research study. Thank you for your interest.

If Eligible: Your answers to the questions indicate you are eligible to participate in this research study. Are you ready to schedule your first study visit?

If No: Thank you very much for listening, have a good day
If Yes: As a part of the research study, we will ask you to complete a physical exercise test. To promote an ideal testing experience, we would like to recommend you complete the following procedures prior to your first visit:
1) Avoid eating food, drinking alcohol, or caffeine or using tobacco products within 2 hours of assessment;
2) Avoid vigorous exercise the day prior to and day of assessment;
3) Wear clothing and footwear to permit athletic movements; specifically running shoes/sneakers and shorts for both males and females; and
4) Drink plenty of fluids the 24-hour period before assessment

Do you agree to do the above activities before your first visit?

☐ Yes Date: _______________ **☐ No**

Name:____

Phone number/email:____

Appendix B **: Questionnaires**

Physical Activity Readiness Questionnaire (PAR-Q)

	Questions	**Yes**	**No**
1	Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?		
2	Do you feel pain in your chest when you perform physical activity?		
3	In the past month, have you had chest pain when you were not performing any physical activity?		
4	Do you lose your balance because of dizziness or do you ever lose consciousness?		
5	Do you have a bone or joint problem that could be made worse by a change in your physical activity?		
6	Is your doctor currently prescribing any medication for your blood pressure or for a heart condition?		
7	Do you know of <u>any</u> other reason why you should not engage in physical activity?		

If you have answered "Yes" to one or more of the above questions, consult your physician <u>before</u> engaging in physical activity. Tell your physician which questions you answered "Yes" to. After a medical evaluation, seek advice from your physician on what type of activity is suitable for your current condition.

<u>Generalized Anxiety Disorder-7 Item (GAD-7)</u>

Over the last 2 weeks, how often have you been bothered by the following problems?	Not at all sure	Several days	Over half the days	Nearly every day
1. Feeling nervous, anxious, or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it's hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid as if something awful might happen	0	1	2	3
Add the score for each column	+	+	+	
Total Score *(add your column scores)* =				

If you checked off any problems, how difficult have these made it for you to do your work, take care of things at home, or get along with other people?

Not difficult at all ___________
Somewhat difficult __________
Very difficult ______________
Extremely difficult __________

Patient Health Questionnaire (PHQ-9)

	Not at all	Several days	More than half the days	Nearly every day
1. Over the *last 2 weeks*, how often have you been bothered by any of the following problems?				
a. Little interest or pleasure in doing things	☐	☐	☐	☐
b. Feeling down, depressed, or hopeless	☐	☐	☐	☐
c. Trouble falling/staying asleep, sleeping too much	☐	☐	☐	☐
d. Feeling tired or having little energy	☐	☐	☐	☐
e. Poor appetite or overeating	☐	☐	☐	☐
f. Feeling bad about yourself or that you are a failure or have let yourself or your family down	☐	☐	☐	☐
g. Trouble concentrating on things, such as reading the newspaper or watching television.	☐	☐	☐	☐
h. Moving or speaking so slowly that other people could have noticed. Or the opposite; being so fidgety or restless that you have been moving around a lot more than usual.	☐	☐	☐	☐
i. Thoughts that you would be better off dead or of hurting yourself in some way.	☐	☐	☐	☐
2. If you checked off any problem on this questionnaire so far, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?	Not difficult at all ☐	Somewhat difficult ☐	Very difficult ☐	Extremely difficult ☐

International Physical Activity Questionnaire (IPAQ)

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?

☐ Yes

☐ No → ***Skip to PART 2: TRANSPORTATION***

The next questions are about all the physical activity you did in the **last 7 days** as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, heavy construction, or climbing up stairs **as part of your work**? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ **days per week**

☐ No vigorous job-related physical activity → ***Skip to question 4***

3. How much time did you usually spend on one of those days doing **vigorous** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads **as part of your work**? Please do not include walking.

_____ **days per week**

☐ No moderate job-related physical activity → ***Skip to question 6***

5. How much time did you usually spend on one of those days doing **moderate** physical activities as part of your work?

_____ **hours per day**
_____ **minutes per day**

6. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **as part of your work**? Please do not count any walking you did to travel to or from work.

_____ **days per week**

☐ No job-related walking ➡ ***Skip to PART 2: TRANSPORTATION***

7. How much time did you usually spend on one of those days **walking** as part of your work?

_____ **hours per day**
_____ **minutes per day**

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the **last 7 days**, on how many days did you **travel in a motor vehicle** like a train, bus, car, or tram?

_____ **days per week**

☐ No traveling in a motor vehicle ➡ ***Skip to question 10***

9. How much time did you usually spend on one of those days **traveling** in a train, bus, car, tram, or other kind of motor vehicle?

_____ **hours per day**
_____ **minutes per day**

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the **last 7 days**, on how many days did you **bicycle** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No bicycling from place to place ➡ ***Skip to question 12***

11. How much time did you usually spend on one of those days to **bicycle** from place to place?

_____ **hours per day**
_____ **minutes per day**

12. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time to go **from place to place**?

_____ **days per week**

☐ No walking from place to place → *Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY*

13. How much time did you usually spend on one of those days **walking** from place to place?

_____ **hours per day**
_____ **minutes per day**

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, chopping wood, shoveling snow, or digging **in the garden or yard**?

_____ **days per week**

☐ No vigorous activity in garden or yard → ***Skip to question 16***

15. How much time did you usually spend on one of those days doing **vigorous** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, sweeping, washing windows, and raking **in the garden or yard**?

_____ **days per week**

☐ No moderate activity in garden or yard → ***Skip to question 18***

17. How much time did you usually spend on one of those days doing **moderate** physical activities in the garden or yard?

_____ **hours per day**
_____ **minutes per day**

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** activities like carrying light loads, washing windows, scrubbing floors and sweeping **inside your home**?

_____ **days per week**

☐ No moderate activity inside home → *Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY*

19. How much time did you usually spend on one of those days doing **moderate** physical activities inside your home?

_____ **hours per day**
_____ **minutes per day**

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

20. Not counting any walking you have already mentioned, during the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time **in your leisure time**?

_____ **days per week**

☐ No walking in leisure time → ***Skip to question 22***

21. How much time did you usually spend on one of those days **walking** in your leisure time?

_____ **hours per day**
_____ **minutes per day**

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **vigorous** physical activities like aerobics, running, fast bicycling, or fast swimming **in your leisure time**?

_____ **days per week**

☐ No vigorous activity in leisure time → ***Skip to question 24***

23. How much time did you usually spend on one of those days doing **vigorous** physical activities in your leisure time?

_____ **hours per day**
_____ **minutes per day**

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the **last 7 days**, on how many days did you do **moderate** physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis **in your leisure time**?

_____ **days per week**

☐ No moderate activity in leisure time → *Skip to PART 5: TIME SPENT SITTING*

25. How much time did you usually spend on one of those days doing **moderate** physical activities in your leisure time?
_____ **hours per day**
_____ **minutes per day**

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekday**?

_____ **hours per day**
_____ **minutes per day**

27. During the **last 7 days**, how much time did you usually spend **sitting** on a **weekend day**?

_____ **hours per day**
_____ **minutes per day**

This is the end of the questionnaire, thank you for participating.

Appendix C **: Clinical Assessments**

Vestibular-Ocular Motor Screening (VOMS) Tool

Vestibular-Ocular Motor Screening (VOMS)

	Not Tested	Headache 0--10	Dizziness 0--10	Nausea 0--10	Fogginess 0--10	Comments
BASELINE	N/A					
Smooth Pursuits						
Saccades – Horizontal						
Saccades – Vertical						
Convergence (Near Point)						**(Near Point in cm):** Measure 1:__________ Measure 2:__________ Measure 3:__________
VOR – Horizontal						
VOR – Vertical						
Visual Motion Sensitivity Test						
Comments:						

Post-Concussion Symptom Scale (PCSS)

No symptoms"0"-------Moderate "3"---------Severe"6"

Time after Concussion

SYMPTOMS	Days/Hrs ________	Days/Hrs ________	Days/Hrs ________
Headache	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Nausea	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Vomiting	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Balance problems	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Dizziness	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Fatigue	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Trouble falling to sleep	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Excessive sleep	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Loss of sleep	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Drowsiness	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Light sensitivity	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Noise sensitivity	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Irritability	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Sadness	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Nervousness	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
More emotional	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Numbness	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Feeling "slow"	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Feeling "foggy"	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Difficulty concentrating	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Difficulty remembering	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
Visual problems	0 1 2 3 4 5 6	0 1 2 3 4 5 6	0 1 2 3 4 5 6
TOTAL SCORE	_____	_____	_____

Modifies Balance Error Scoring System (mBESS)

Score Card

Balance Error Scoring System (BESS)
(Guskiewicz)

Balance Error Scoring System – Types of Errors
1. Hands lifted off iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position >5 sec
The BESS is calculated by adding one error point for each error during the 6 20-second tests.

SCORE CARD: (# errors)	FIRM Surface	FOAM Surface
Double Leg Stance (feet together)		
Single Leg Stance (non-dominant foot)		
Tandem Stance (non-dom foot in back)		
Total Scores:		
BESS TOTAL:		

Which **foot** was tested: ☐ Left ☐ Right
(i.e. which is the **non-dominant** foot)

Exit Score Sheet

Assessment Information

Date ____________

Start Time ____________

BP pre: _____/_____

post: _____/_____

HR pre: ____________

post: ____________

Testing Order

__1__ Aerobic (HIIT)
Version (circle):
1 2 3 4 5 6

_____Dynamic Circuit
_____Ball Toss Version
_____Box Drill (Shuffle)
_____Box Drill (Carioca)
_____ Zig Zag Drill
_____Pro Agility
_____Arrow Agility

Internal Use

Site:______________________

☐ Past medical history reviewed on intake

Aerobic Protocol

Gender	Athlete Type	Treadmill Version	Treadmill Speed (mph) LOW	Treadmill Speed (mph) HIGH	Pacer (10 m) Version	Pacer Time (sec) LOW	Pacer Time (sec) HIGH
Female	Moderate	**1**	**4.0**	**6.0**	**5**	**4.5**	**4.0**
	Advanced	**2**	**4.5**	**7.0**			
Male	Moderate	**3**	**4.5**	**7.5**	**6**	**4.0**	**3.5**
	Advanced	**4**	**5.5**	**8.5**			

Aerobic Component

Time	HA	DZ	NA	RPE	HR
0 (Pre)					
2 (Warm-up)					
6:30-7					
12 (Finish)					

Assessment Notes

☐ Symptoms worsened during assessment

Inability to maintain pace/physical demands and
☐ modified, explain:

☐ discontinued, explain:

☐ Other:

End Time (if DNF): ____________

Dynamic Movement Component

Task	HA	DZ	NA	RPE	HR	Errors	Time
Dynamic Circuit							
Ball Toss							
Box Drill (Shuffle)							1. 2.
Box Drill (Carioca)							1. 2.
Zig-Zag							1. 2.
Pro Agility							1. 2.
Arrow Agility							1. 2.

<u>Assessment Notes</u>

☐ Symptoms worsened during assessment

Inability to maintain pace/physical demands and

☐ <u>modified,</u> explain:

☐ <u>discontinued,</u> explain:

☐ Other:

End Time (if DNF):____________

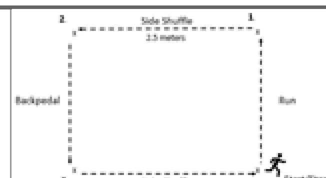
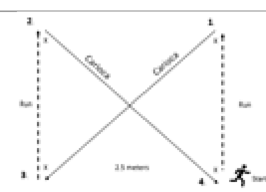
Sport Specific/Contact activities:

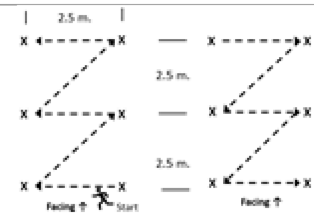
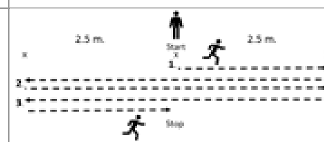
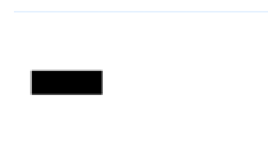
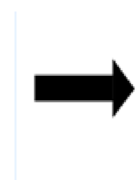
Clinical Interpretation

☐ Pass ☐ Deconditioned ☐ Symptomatic/Fail

<u>Recommendations:</u>

<u>EXIT Dynamic Agility Tasks</u>

Set Up: Place 6 agility cones 2.5 meters apart in a rectangle (2 rows with 3 cones each) **Instructions and demonstrations for each task were provided during the break between tasks. All tasks will begin with a "3, 2, 1, GO" count.** **Participants complete 2 trials for each task with a 30 second rest between trials (except Pro Agility-15 seconds)**		
Box Drill Shuffle	Athlete will sprint forward to the first cone, side shuffle to the second cone, backpedal to the 3rd cone, and side shuffle to the "start" cone. After completing 2 "laps", immediately repeat in the opposite direction (4 total circles), rest for 30 seconds. Repeat.	
Box Drill Carioca	Athlete will sprint forward to the first corner, carioca diagonally backwards to the 3rd corner. Sprint to the 2nd corner, and carioca backwards diagonally to the "start" corner. After completing 2 "laps", rest for 30 seconds. Repeat.	

Zigzag	Athlete will side-shuffle to the left, touch the cone, and side shuffle diagonally to the right cone and repeat for remaining cones. After reaching the final cone, maintain body facing the same direction and continue to side-shuffle touch each cone in reverse order (starting with a lateral shuffle back to the right. Repeat with a backwards shuffle to the start cone. Complete 2 "laps", Rest for 30 seconds. Repeat.	
Pro Agility	Begin standing between 2 end-cones and facing perpendicular to cones. When cued, turn right, sprint to touch the right cone (2.5m), turn and sprint to the far left cone (5m), touch cone, turn and run to touch each end cone one additional time (5m each), before sprinting through the start cone (middle). Rest 15 seconds. Repeat with initial direction to left.	
Arrow Agility	Athlete begins at the same position as Pro Agility task. Administrator presents a card that has a block on the left or right side which correspond to each end cone. Subject is instructed to run, touch the cone, and return to the starting point as quickly as possible, at which point the clinician presents the next card. A series of 16 cards (8 left, and 8 right) are presented in a randomized order. Upon completion of all 16, rest for 30 seconds. During rest, athlete is instructed to repeat task, running to the direction of the arrow, regardless of its spatial location (left or right) on the card. A series of 16 cards are randomly presented, the cards include congruent (box-left/arrow-left and box-right/arrow-right) and incongruent (box-left/arrow-right and box-right/arrow-left) combinations that are each presented with 4 trials.	 

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