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Research Article

Impact of Acute Exercise on Baseline Concussion Measures

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Abstract

Concussions present with a myriad of symptoms and deficits related to balance, cognition, and vestibular/ocular motor assessments. To increase accuracy in concussion diagnosis and management, baseline assessments are recommended to provide individualized, pre-injury assessment measures. While symptom reduction and recovery may be aided by physical activity post-concussion, further information is needed to understand the potential influence of post- exercise symptoms in healthy athletes. Therefore, the purpose of this study was to compare the effects of acute exercise on baseline measures of concussion including the SCAT5, KD, ImPACT, BESS, and VOMS. We completed a cross-sectional, laboratory study with 1 independent variable group (exercise, control). Subjects were matched on sex, age, and sport- related concussion (SRC) history and then randomly allocated into the exercise or control group prior to data collection. The dependent variables were comprised of outcome scores from the ImPACT, SCAT5, BESS, VOMS, and K-D test. A total of 93 recreationally active college students (age range = 18-24 years; physical exertion n = 47, control n = 46) were recruited to participate in this study. The exercise group engaged in a one-time, 15-minute exercise protocol before completing the SRC assessments, while the control group completed the SRC assessment protocol in a rested state. Significant differences were noticed between groups on SCAT total number of symptoms and symptom severity, as well as ImPACT symptom severity score, with the control group scoring higher in all categories. For future practice, sports medicine professionals should consider the effect exercise may have on baseline measurements of concussions, specifically symptoms. It may be beneficial to conduct baseline measurements after practice or conditioning, for a better indication of the athlete's true baseline. Additionally, it is important that clinicians and sports medicine professionals continue to use a multimodal approach when treating concussions, as symptoms alone may not be a good indication.

Keywords: Exercise; Sport Concussion; Somatic; Cognitive; Emotional.

Introduction

Concussions present with a myriad of symptoms and deficits related to balance, cognition, and vestibular/ocular motor assessments [1]. To increase accuracy in concussion diagnosis and management, baseline assessments are recommended to provide individualized, pre-injury assessment measures [2]. Currently, some sports medicine practitioners administer baseline concussion assessments at rest, prior to beginning their competitive season. Meanwhile, athletes are often in a state of physical exertion during a concussive event and therefore, the sideline assessment, further creating a challenge for diagnosing and managing the suspected injury. While consensus statements also recommend that baseline and post-injury assessments be administered in similar environments that maximize the patient's abilities [2] it remains unclear whether baseline assessment should account for physical activity and exertion.

Consensus statements continue to recommend the most recent version of the Sport Concussion Assessment Tool (SCAT) as a tool to evaluate an athlete for a suspected concussion [1]. To better understand the effects of exercise on the SCAT as a sideline tool, Lee et al. [3] compared baseline performance at-rest and after exercise. Following exercise, athletes reported more symptoms as compared to at-rest, while also noting decreased balance measures post-exercise. However, no differences were noted on cognitive tasks, such as orientation, memory, or concentration, nor Standardized Assessment of Concussion (SAC) scores. Similar results were noted by Moran et al. [4], who noted worse total symptoms, symptom severity, and somatic, cognitive, emotional, and fatigue/sleep symptom factors scores following a maximal bout of exercise. Additionally, postural control sway scores also worsened when compared to pre- and post-exercise. Covassin and colleagues [5] noted worse measures of verbal memory following maximal exertion testing compared to at-rest, while others have reported worse visual memory, reaction time, and impulse control in athletes who exercised within 3 hours of completing their baseline assessment [6].

Post-exercise deficits related to balance have also been observed, with an increase in total number of errors on the balance error scoring system (BESS) [3,7,8]. Differences have been reported between at-rest and post-exercise assessment, [3] as well as between exercise and control groups on the BESS test [7,8]. Additionally, tandem gait, a measure of dynamic balance, has been reported to be influenced by exercise [3,9]. Post-exercise, athletes require more time to complete the tandem gait test than at-rest, [3,9] further highlighting the concern of accurate sideline assessment, if comparing post-concussion evaluations with at-rest baseline assessments.

With recent implementation of vestibular and ocular motor assessment into concussion diagnosis and management, very few studies have examined the effects of exercise in this domain. Moran and colleagues were one of the first to explore the effects of exercise on the Vestibular/Ocular Motor Screen (VOMS), a vestibular and ocular symptom provoking assessment tool growing popularity as a valid concussion assessment tool. VOMS provocation scores did not differ from pre- to post-exercise among college aged individuals, however there was a significant improvement in visual motion sensitivity symptoms following 20-minutes of rest post-exercise when compared to pre-exercise levels. Unlike areas of cognition and balance that display with deficits following exertion, King-Devick test scores have been found to improve after exercise, as compared to at-rest assessment [10,11]. Post-exercise times were reported to have improved by approximately 4-seconds in both high school [10] and collegiate [11] athletes.

While worse scores at post-exercise may allow a sports medicine professional to keep that athlete out of play due a false-diagnosed concussion, improved scores would allow for the potential to have an athlete un-diagnosed with a suspected concussion, due to improvements from at-rest baseline. Additionally, improvements in post-injury measures may be influenced positively by exercise. Preliminary evidence yielded that sub-symptom exercise in athletes with post- concussion syndrome saw a reduction in the duration of symptoms and improved recovery, however data are limited and remain as predominately, case-study-design investigations [12-14]. While symptom reduction and recovery may be aided by physical activity post-concussion, further information is needed to understand the potential influence of post-exercise symptoms in healthy athletes. Therefore, the purpose of this study was to compare the effects of acute exercise on baseline measures of concussion including the SCAT5, KD, ImPACT, BESS, and VOMS.

Methods

We completed a cross-sectional, laboratory study with 1 independent variable group (exercise, control). Subjects were matched on sex, age, and sport-related concussion history and then randomly allocated into the exercise or control group prior to data collection. The dependent variables were comprised of outcome scores from the ImPACT, SCAT5, BESS, VOMS, and K- D test.

Participants

A total of 93 recreationally active college students (age range = 18-24 years; physical exertion n = 47, control n = 46) were recruited to participate in this study from three different higher education institutions (Table 1). We defined recreationally active as engaging in at least 30 minutes of aerobic physical activity at least two times per week, with aerobic activity being any bodily movements produced by the contraction of skeletal muscles that increases the heart rate and energy expenditure more so than activities of daily living. Subjects were included if they were enrolled as a student at a college/university, were recreationally active, had a resting heart rate between 60-110 beats per minutes, and a blood pressure less than or equal to 140/90.

Age	**M (SD)**
Control	21.1 (1.7)
Exercise	20.9 (1.6)
Total	21.0 (1.7)
Sex	**Male (%)**
Control	26 (56.5)
Exercise	26 (55.3)
Total	52 (56.0)
Concussion History	**Yes (%)**
Control	11 (23.9)
Exercise	12 (25.5)
Total	23 (24.7)

Table 1: Demographic Information by Group (Control N = 46; Exercise N = 47)

Subjects were excluded if they did not speak and/or read English, had suffered a concussive injury within the past three-months, had lingering concussion symptoms from an injury, or if they answered 'yes' to one or more of the Physical Activity Readiness Questionnaire Plus (PAR- Q+) questions or two or more of the American Heart Association (AHA)/American College of Sports Medicine (ACSM) Health Screening Questionnaire. The PAR-Q+ is a 7-item questionnaire that is used to determine health status as it relates to participating in physical activity, and the AHA/ACSM Health Screening Questionnaire includes 31-items that pertain to general health history issues and cardiovascular risk factors that would require an individual to undergo an evaluation by a physician before engaging in physical activity. Individuals were also excluded if they had a history of diagnosed attention deficit hyperactivity disorder, a learning disability, chronic headache or migraine disorder, motion sickness, or vertigo. These exclusionary criteria were used to decrease the risk of injury for subjects completing the exercise protocol and to minimize variables that may alter concussion baseline performance.

This study was approved by the human research ethics committees at the participating institutions. This was a sample of convenience, and recruitment occurred by the research team verbally providing students majoring in health-related field with information about the study prior to or following a course lecture or lab. In order to maintain confidentiality and limit coercion, interested individuals were directed to contact the researchers via e-mail if they were interested in participation. All subjects provided written informed consent prior to completing the data collection procedure.

Instruments

The level of physical exertion was monitored for exercise participants using a Polar heart rate monitor and the Borg Rating of Perceived Exertion (RPE) Scale. The Polar heart rate monitors were used to track heart rate, and consisted of a watch and chest heart rate sensor that the subjects wore while exercising. The Borg RPE scale is a simple, subjective measure of physical activity intensity level [15]. The scale ranges from 6 (no exertion at all) to 20 (maximal exertion), and exercise subjects were asked to self-report their RPE throughout the physical exertion protocol.

A battery of sport-related concussion management tools (i.e., ImPACT, SCAT5, BESS, VOMS, K-D test) were used in this study. The ImPACT is a 20-30 minute computerized neurocognitive test that is used for baseline and post-concussion injury management and includes a patient demographic section, post-concussion symptom rating scale, and size subtests that yield four composite scores (i.e., verbal memory, visual memory, processing speed, reaction time). [16].

The SCAT5 is a 15-minute standardized sport-related concussion evaluation tool that includes both on-field and off-field injury assessments [17]. This study utilized the following components from the SCAT5 off-field assessment: symptom evaluation, the Standardized Assessment of Concussion (SAC) cognitive screening (orientation, immediate memory, digits backwards, months in reverse order, delayed recall), and the BESS. The BESS is a 3-5 minute measure of postural stability in three stances (double leg, single leg, tandem) on two surface conditions (firm ground, Airex balance pad) [18]. Each stance was completed for 20 seconds in both surface conditions, and a total BESS score was calculated by adding 1 point for every stance deviation error recorded across all test conditions.

The VOMS is a brief screening tool used to assess vestibular and ocular motor function during and following the completion of smooth pursuits, horizontal saccades, vertical saccades, horizontal vestibular ocular reflex (VOR), vertical VOR, visual motion sensitivity (VMS), and near point convergence (NPC) tasks [19]. Subjects self-reported symptoms of headache, dizziness, nausea, and fogginess after each component on a scale ranging from 0 (none) to 10 (severe).

Additionally, NPC was further assessed through an objective measurement in centimeters from the point of convergence to the tip of the nose.

The K-D test is a rapid number naming assessment that takes less than 2 minutes to administer [20,21]. Subjects completed two trials where they read single digit numbers from left to right as fast as they could from three test cards that increased in difficulty. The K-D test summary score represented the sum of time it took the subject to complete all test cards without committing errors. The fastest trial time was used for this study.

Procedures

After giving consent, participants underwent further screening via the PAR-Q+ and AHA/ACSM Health Screening Questionnaire to ensure they were eligible for this study. After being matched and randomized into either the exercise or control group, subjects then completed the data collection procedure. The exercise group engaged in a one-time, 15-minute exercise protocol before completing the sport-related concussion assessments, while the control group completed the sport-related concussion assessment protocol in a rested state. The exercise protocol consisted of running/jogging on a treadmill or an elliptical at 60-80% of the subject's age-predicted heart rate (APHR) maximum. Subjects had full control to adjust their intensity, speed, and incline as needed throughout the exercise protocol. Subjects reported their RPE and heart rate monitor reading every two minutes while exercising. If the subject's heart rate surpassed 80% of their APHR, they had five minutes to reduce their heart rate back into the target zone; if they were unable to do so, the protocol would be stopped. Additionally, if the subject reported a 19 or greater on the RPE scale at any time, the protocol would be stopped. This was not necessary for any participant within the study. The sport-related concussion assessment protocol included subsequent measures of neurocognitive performance (ImPACT; SCAT5), balance (BESS), and vestibular and oculomotor performance (VOMS; K-D test). The sport-related concussion assessments were completed in a randomized order that varied from subject to subject. All assessments were conducted by skilled researchers or research assistants who previously underwent training in the proper administration of each test. All scores were recorded via paper and pencil during the data collection sessions and were entered into an IBM Statistical Package for the Social Science (SPSS Version 23) data file for cleanup and statistical analysis.

Results

Demographics

Participants were matched on gender, age, and concussion history, to eliminate any potential confounding variables. Therefore, no differences existed between groups on age (t = .612, p =.192), sex (x^2 = .014, p = .907), or concussion history (x^2 = .033, p = .856; Table 1).

Group Differences

Beyond descriptive statistics, multiple independent study t-tests were run to explore differences between groups (i.e., control and exercise). No statistical significance was found between groups on SCAT total score, KD baseline time, BESS total score, or ImPACT composites (verbal memory, visual memory, visual motor speed, reaction time). Significant differences were noticed between groups on SCAT total number of symptoms and symptom severity, as well as ImPACT symptom severity score, with the control group scoring higher in all categories (Table 2).

Sport	**M (SD)**	**t**	**df**	**p-value**
SCAT Total Score				
Control	33.09 (5.67)			
Exercise	31.38 (5.49)			
Total	32.23 (5.61)	1.47	91	.144
SCAT Symptom Number				
Control	2.22 (3.28)			
Exercise	.83 (1.58)			
Total	1.52 (2.64)	2.59	64.49	.012*
SCAT Symptom Severity				
Control	3.50 (5.75)			
Exercise	1.17 (2.37)			
Total	2.32 (4.51)	2.55	59.63	.013*
KD Baseline Time				
Control	42.37 (5.82)			
Exercise	41.08 (6.83)			
Total	41.71 (6.35)	0.96	88	0.34
Verbal Memory				
Control	86.20 (11.79)			

Exercise	84.77 (12.39)			
Total	85.47 (12.05)	5.70	91	.570
Visual Memory				
Control	75.28 (10.84)			
Exercise	70.19 (14.76)			
Total	72.71 (13.15)	1.89	88	.062
Motor Speed				
Control	38.12 (5.88)			
Exercise	36.56 (6.22)			
Total	37.33 (6.07)	1.24	91	.570
Reaction Time				
Control	.66 (.10)			
Exercise	.51 (1.06)			
Total	.58 (.76)	0.98	91	.330
Symptom Severity				
Control	5.54 (7.67)			
Exercise	2.81 (5.01)			
Total	4.16 (6.58)	2.03	77.25	.046*
BESS Total Score				
Control	11.93 (4.30)			
Exercise	12.49 (5.79)			
Total	12.22 (5.09)	-.52	91	.602

Table 2: Results of T-Test for Group Comparisons of Baseline Measures (Control N = 46; Exercise N = 47); Notes: *significant at p < .05

While not significant, there was a trend for the visual memory composite on ImPACT, where the exercise group scored higher than the control group. A multivariate analysis of variance (MANOVA) was used to explore differences between groups on VOMS symptoms. Using Wilks statistic, there was no significant effect of group (control, exercise) on VOMS symptoms (F(23,67) = .342, p = .279). Separate univariate analyses revealed no significant differences between groups across any symptoms following VOMS administration (Table 3).

	Control		**Exercise**				
Measure	**Mean**	**SD**	**Mean**	**SD**	**F**	**p-value**	**Partial η2**
Smooth Pursuits							
Headache	.22	.664	.11	.521	.182	.670	.002
Dizziness	.09	.354	.09	.282	.001	.977	.000
Nausea	.07	.327	.02	.146	.707	.403	.008
Fogginess	.09	.463	.04	.204	.361	.549	.004
Horizontal Saccades							
Headache	.22	.664	.11	.521	.182	.670	.002

Dizziness	.11	.379	.15	.416	.055	.815	.001
Nausea	.07	.327	.02	.146	.707	.403	.008
Fogginess	.15	.556	.13	.494	.001	.979	.000
Vertical Saccades							
Headache	.2	.619	.13	.536	.001	.978	.000
Dizziness	.2	.582	.13	.397	.437	.510	.005
Nausea	.07	.327	.02	.146	.707	.403	.008
Fogginess	.15	.556	.11	.375	.063	.803	.001
Convergence							
Headache	.20	.582	.17	.637	.129	.720	.001
Dizziness	.20	.500	.06	.247	2.626	.109	.029
Nausea	.09	.354	0	.000	2.834	.096	.031
Fogginess	.13	.499	.06	.247	.671	.415	.007
Horizontal VOR							
Headache	.17	.529	.26	.765	.913	.342	.010
Dizziness	.57	.834	.51	.831	.332	.566	.004
Nausea	.13	.619	.00	.000	2.093	.152	.023
Fogginess	.15	.631	.13	.619	.000	.982	.000
Vertical VOR							
Headache	.20	.619	.23	.698	.390	.534	.004
Dizziness	.30	.726	.36	.705	.154	.696	.002
Nausea	.11	.605	.00	.000	1.520	.221	.017
Fogginess	.15	.631	.09	.458	.346	.558	.004
VMS							
Headache	.17	.608	.21	.657	.433	.512	.005
Dizziness	.57	.981	.38	.573	.727	.396	.008
Nausea	.13	.757	.00	.000	1.428	.235	.016
Fogginess	.15	.556	.09	.351	.231	.632	.003

Table 3: Results of Multiple Univariate Analyses for Group Comparisons of Baseline VOMS Symptom Measures (Control N = 45; Exercise N = 46).

Discussion

In this study, no significant differences were noted between groups based on acute exercise on neurocognitive, balance, vestibular, or oculomotor measures. However, differences between groups (control, exercise) were noted on number of symptoms and symptom severity on both ImPACT and SCAT5. These findings suggest exercise may have an effect on symptoms athletes report at baseline, and potentially after injury.

Noting the differences in symptoms between groups, those in the control group were more likely to report more symptoms and more severe symptoms. Exercise has previously been shown to be associated with lower state anxiety. In fact, even low-intensity exercise has been shown to improve general affect. Further, exercise has been demonstrated to be related to positive changes in mood state. There are physiological reasons that may explain the positive impact on psychological well-being including: increases in cerebral blood flow and changes in neurotransmitters. Additionally, the individual may find enjoyment in the activity and increased feelings of control, competency, and self-concept, which may all relate to increases in overall psychological well-being. Because of these factors, it is possible that acute exercise reduced some of the symptoms regularly measured on concussion tests.

The trend for differences on visual memory is not surprising given previous research has found a relationship between acute exercise and working memory. While the relationship isn't exact, and varies based on type and intensity of activity, there remains an impact of acute exercise on working memory. This relationship may explain the trend noted with the exercise group scoring better on the visual memory component of ImPACT, though again, this was not a significant finding.

The study lends support for a multimodal approach to concussion management. It has now become standard practice to evaluate individuals at baseline and after a suspected concussion using multiple assessment tools. These tools should go beyond symptoms and include neurocognitive, balance, vestibular, and oculomotor measurements. As noted in the current study, simply measuring symptoms may not give a clear indication of an athlete's injury status. If athlete baseline measures are gathered at rest, when a subsequent concussion occurs during activity, the symptom measurement may be skewed, given athletes tend to report more symptoms at rest than after exertion. Further, athletes are known to not always report concussions, including possible symptoms. Therefore, sideline measures such as VOMS and SCAT5 may be useful in giving a more robust picture of the athlete's status.

Some strengths of the study include a relatively large sample size, including both male and female participants. Additionally, participants were matched on age, sex, and concussion history to avoid any confounding variables. Further, athletes were excluded if they had recently sustained a concussion to eliminate the possibility of latent concussive symptoms. Despite the study's strengths, there are some limitations in the study, including the exercise protocol itself. It is possible the exercise protocol was not a true representation of the exertion an athlete would typically undergo during practice or competition. However, increasing exertion may have had a greater impact on symptoms and working memory, thus it is hard to discern how the level of exercise may have impacted the findings. Further, the study used a convenience sample of college students and thus may not be representative of collegiate athletes. These limitations notwithstanding, the findings of this study have implications on how baseline data is collected and how suspected concussions are measured on the sideline.

Future research should explore the effect of different levels of exercise intensity on baseline concussion measurements. Additionally, future research should specifically look at athletes, as well as different levels of athletes. For future practice, sports medicine professionals should consider the effect exercise may have on baseline measurements of concussions; it may be beneficial to conduct baseline measurements after practice or conditioning, for a better indication of the athlete's true baseline. Additionally, it is important that clinicians and sports medicine professionals continue to use a multimodal approach when treating concussions, as symptoms alone may not be a good indication.

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