Microhematuria Associated with a Special Operations Craft Mission

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ABSTRACT

Microhematuria is a common consequence of high-impact exercise such as running and jumping. In order to determine whether or not a similar hematuria accompanies mechanical shock exposure associated with small boat operations in the open ocean, urinary variables were measured in two boat crews (total N = 12) during a 2-day Mk V Special Operations Craft transit down the eastern coast of the United States and a 2-day recovery period. One boat was fitted with experimental shock-mounted seats, the other with standard-issue seats. Microhematuria and microalbuminuria were found in samples taken prior to and during the transit. Levels of microhematuria and microalbuminuria were similar to those seen in athletes competing in intense running events. Levels of creatinine, free and total hemoglobin and urine blood coloration decreased significantly following the transit, but urinary albumin did not. Statistical comparison of urinary constituents between boats was not possible because of the small sample size and unmeasured variability in shock exposure between boats. However, medium to large effect sizes were found in the measures of urinary creatinine, hemoglobin, and urine color between the different craft crews, particularly the morning after the most demanding day. It was concluded that the microhematuria seen appears benign, but these measures may be useful in quantifying levels of mechanical shock exposure.

1. INTRODUCTION

U.S. Navy Special Warfare Combatant-craft Crewmen (SWCC) are routinely exposed to severe boat-wave impacts during mission training and execution. Peak accelerations of up to 12 g have been recorded on the U.S. Mk V Special Operations Craft (SOC), and impacts up to 3 g appear common. The faster a boat travels over heavy seas, the greater the impact with the water's surface. This impact is transferred directly into the back, knees, neck, muscles, and other joints of the boat operators. In extreme cases, such impacts result in

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14. ABSTRACT

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whiplash, herniated disks, and vertebral fracture. Even in less severe cases, the resulting injuries cause fatigue, and extreme discomfort and pain [1].

Hematuria, the presence of red blood cells in the urine, is commonly found in runners and other high-impact sport athletes [2-4]. This exercise-induced hematuria is often accompanied by proteinuria, the presence of proteins, usually albumin, in the urine. This syndrome has been attributed to continuous minor trauma to the kidney and other organs of the urogenital tract (e.g., bladder, urethra, or prostate, in men), increased renal venous pressure, transient renal ischemia, and dehydration. In general the greater the mechanical shock involved (running > bicycling; sprinting > jogging), and/or the greater the duration of the impact exercise, the greater will be the degree of hematuria [3,5-8]. The syndrome is usually benign and resolves within 24 to 72 hours. However, if it persists longer, other problems such as kidney trauma or other diagnoses may exist. Hematuria is considered gross hematuria when the blood is clearly visible in the urine and microhematuria when blood cells are detected but not overtly visible.

Gross hematuria has been reported anecdotally in SWCC following particularly rough missions. In general, such events are reported to abate quickly, and appear to present no lingering problems for those afflicted. Nonetheless, such reports suggest that hematuria similar to that found in athletes may exist for SWCC. If so, the measurement of the magnitude of the hematuria may offer a method for estimating the intensity of shock exposure. In an attempt to determine the presence of hematuria in SWCC associated with Special Boat operations and whether any hematuria may be related to aspects of the boat mission, urinary responses were measured during a 2-day Mk V SOC transit down the eastern coast of the United States and a 2-day recovery period.

2. METHODS

On January 10 and 11, 2003, members of a Mk V SOC detachment of Special Boat Team 20 (N = 12) participated in a transit of 2 Mk V SOC from Naval Amphibious Base, Little Creek, VA, to Naval Submarine Base, Kings Bay, GA, a distance of approximately 600 nautical miles. The transit took 2 days with an overnight stop in Southport, NC. Of the 2 Mk V SOC, one was fitted with 6 experimental shock-mounted seats for the crew; the other retained the original equipment seats that were not fitted with shock-absorbing hardware.

The transit consisted of 2 days with underway periods. During the first day, the boats were underway for 13.5 hours in seas with wave heights of 5-6 feet. During the second day, the boats were underway for only 9 hours, and the wave heights were 3-4 feet.

2.1. Subjects

Subjects in this study were 12 SWCC, attached to Special Boat Team 20 in Norfolk, VA. Physical characteristics are provided in Table 1. Prior to the transit, the boat crews had spent the entire week training on various boat operations and participating in regular physical training. The crew of the experimental-seat boat did not go out on their boat the night prior to the transit. Their boat was being outfitted with the instrumentation required for this study. However, some of them chose to train with another boat crew.

Table 1. Study Participant Physical Characteristics

	Experimental Group (Special Boat Team 20)
Number of participants	12
Age (y)	30.7 (8.3)
Stature (cm)	172.0 (6.5)
Weight (kg)	79.0 (10.4)
Body Mass Index (kg·cm^2)	26.6 (2.5)

2.2. Data Collection

Urine samples were collected 4 times during the transit and 3 times during the 2 days following the transit. The schedule of sample collection is provided in Figure 1. Urine was collected using a midstream catch in a standard urine collection cup, and stored on ice. The urine samples were aliquoted into two 4.5-mL cryotubes and placed in -80°C storage until analyzed. All stored specimens were shipped to the biochemical analysis laboratory on dry ice, and upon arrival placed in an -80°C freezer until analysis procedures began.

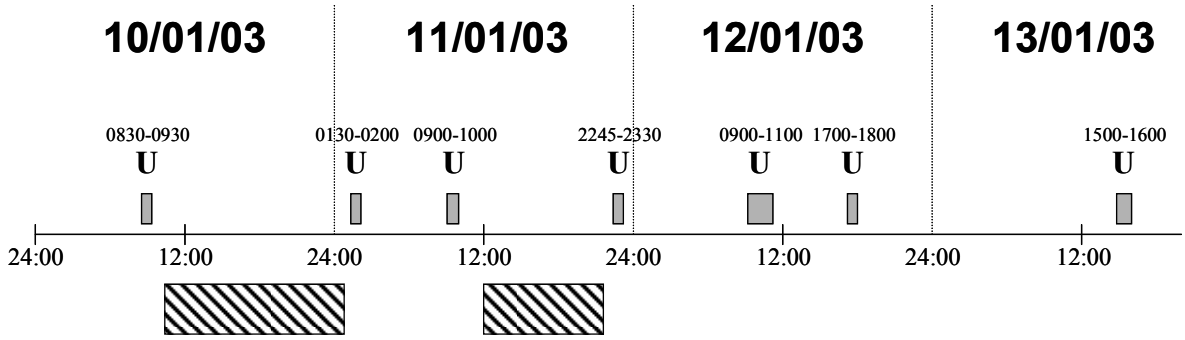

Figure 1. Data collection time line. Horizontal axis shows clock time for the dates indicated. Hatched bars indicate underway periods. Solid gray bars indicate periods of sample collection. "U" indicates that a urine sample was collected.

2.2.1. Measures

The urinary constituents measured are listed below with a brief explanation of the analytical methods used for their determination. All analytical procedures were carried out in duplicate. When constituent values were outside reference values, an additional analysis was carried out to confirm the measurement.

Creatinine – Urinary creatinine was measured using the Vitros Clinical Chemistry slide technology, which uses the Jaffe chemical reaction as the basis for measurement. Vitros slides were analyzed and quantified using a Kodak DT-60 Chemistries analyzer (Johnson & Johnson Co., Kodak Corp.).

Specific Gravity – Urine specific gravity was measured by refraction using a Fisher Urinary Refractometer (Fisher Chemical Co.). The mean value of the duplicate determinations served as the score for data records.

Osmolality – The determination of osmolality was based on freezing point depression and measured using an Osmette series osmometer calibrated with a 2-point standard (Precision Systems, Inc.).

Albumin – Albumin determination was based upon a dye binding procedure using a sulfonephthalein dye (bromcresol green reaction) held to an adjusted, constant pH. Color development was quantified with a spectrophotometer (Fisher Chemical Co., Thermo DMA Corp.)

Urinary Blood Coloration – All urinary specimens were visually inspected (one technician) for the outward color signs of the presence of blood. A numerical scaling (Clintek – Bayer Corp.) was used to rate the specimens (0 = none visible; 1 = positive; 2 = very positive, and so on).

Hemoglobin – Hemoglobin was determined with a colorimetric assay using the cyanmethoglobin reaction. Color development was quantified with a spectrophotometer (Fisher Chemical, Bayer Corp.). Both Free Hb and Total Hb were measured. For Free Hb, a urine specimen was centrifuged (4°C, 15000 RPM, 5 min) to separate erythrocytes, and particulate matter. A clear, free supernate was extracted from the top of the specimen and analyzed. For Total Hb, urine specimens were nutated until in equilibrium, a supernate contacting erythrocytes extracted and analyzed (Fisher Chemical Co., Bayer Corp).

2.2.2. Data Analysis

Statistical procedures were carried out using SPSS for Windows, v11.0 (SPSS, Inc., Chicago, IL). The sample size was too small to provide meaningful statistical analysis. The sample size for analyses requiring a complete set of measures was 9 (4 in the craft with standard seats, 5 in the craft with shock-mounted seats). A mixed-design analysis of variance (ANOVA) was carried out using sample number as the within-person effect and craft (standard seats vs. shock-mounted seats) as the between-subjects effect. No significant main effects or interactions were found. Typical power values for this analysis were in the range of 0.1 to 0.4. Therefore, the study was treated as a pilot effort. By presenting these data, we hope to provide results that can be considered in hypothesis generation in further work. Differences among mean values were evaluated using Cohen's *d* as an indicator of effect size [9]. Cohen's *d* is calculated as:

$$d = \left(M_1 + M_2\right) \Big/ \sqrt{(\sigma_1^2 + \sigma_2^2)/2}$$

where: M_1 and M_2 are mean values and σ_1^2 and σ_2^2 are the standard deviations for variables 1 and 2, respectively. Following Cohen's suggestion, values of *d* greater than 0.5 (69th percentile, and 66% overlap of the two distributions compared) were considered "medium" effect sizes, and values of *d* greater than 0.8 (79th percentile and 52.6 % overlap) were considered "large" effect sizes for discussion purposes.

Table 2. Mean Values* of Urine Measures

Variable	Craft	1st Morning	1st Evening	2nd Morning	2nd Evening	3rd Morning	3rd Evening	4th Evening
Number of subjects	Std. Seats	6	5	6	6	5	6	6
	Exp. Seats	6	6	6	6	5	6	6
	Total	12	11	12	12	11	12	12
Creatinine (mg·dL-1)	Std. Seats	176.1 (79.5)	167.3 (58.9)	199.4 (26.2)	154.8 (47.5)	124.7 (73.3)	142.4 (57.5)	139.4 (44.5)
	Exp. Seats	182.2 (33.6)	157.0 (78.7)	168.6 (56.6)	155.5 (64.5)	141.0 (81.9)	155.1 (40.3)	110.7 (49.9)
	Total	179.2 (58.3)	161.7 (67.1)	184.0 (45.1)	155.1 (54.0)	132.8 (73.8)	148.8 (47.8)	125.1 (47.5)
Urine specific gravity	Std. Seats	1.024 (0.013)	1.027 (0.014)	1.030 (0.010)	1.025 (0.010)	1.020 (0.012)	1.022 (0.008)	1.025 (0.012)
	Exp. Seats	1.031 (0.006)	1.027 (0.012)	1.021 (0.008)	1.028 (0.011)	1.021 (0.011)	1.025 (0.010)	1.017 (0.009)
	Total	1.028 (0.011)	1.027 (0.012)	1.025 (0.010)	1.027 (0.010)	1.021 (0.011)	1.023 (.009)	1.021 (0.011)
Urine osmolality (mOsm·kg-1)	Std. Seats	821 (353)	811 (368)	735 (210)	743 (180)	588 (350)	727 (211)	717 (158)
	Exp. Seats	956 (207)	727 (335)	718 (323)	801 (452)	738 (445)	819 (146)	604 (181)
	Total	889 (285)	765 (335)	727 (260)	772 (329)	663 (386)	773 (180)	661 (173)
Urinary albumin (mg·L-1)	Std. Seats	66.1 (2.0)	71.1 (7.4)	77.5 (12.1)	67.6 (10.1)	61.9 (5.0)	65.4 (4.7)	65.8 (5.7)
	Exp. Seats	87.1 (50.9)	86.1 (33.8)	70.9 (10.0)	73.5 (7.8)	68.1 (6.9)	66.9 (4.2)	68.7 (5.0)
	Total	76.6 (36.0)	79.3 (25.6)	74.2 (11.1)	70.5 (9.1)	65.0 (6.6)	66.1 (4.3)	67.3 (5.3)
Urinary albumin/creatinine (mg·g-1)	Std. Seats	53.1 (44.9)	46.9 (15.8)	38.8 (2.8)	49.3 (22.9)	70.4 (45.6)	54.2 (26.4)	51.5 (16.8)
	Exp. Seats	49.0 (28.0)	70.1 45.5)	47.9 (23.4)	55.0 (23.0)	67.1 (47.5)	45.7 (12.2)	73.0 (30.6)
	Total	51.1 (35.7)	59.5 (35.8)	43.4 (16.6)	52.2 (22.1)	68.8 (43.9)	49.9 (20.1)	62.2 (26.0)
Urine color (0-5 Scale)	Std. Seats	0.67 (0.52)	0.80 (0.44)	1.50 (0.84)	0.67 (0.52)	0.40 (0.55)	0.05 (0.55)	0.67 (0.52)
	Exp. Seats	0.67 (0.52)	0.83 (0.41)	0.67 (0.52)	0.50 (0.84)	0.80 (0.45)	0.17 (0.41)	0.17 (0.41)
	Total	0.67 (0.49)	0.82 (0.40)	1.08 (0.79)	0.58 (0.67)	0.60 (0.52)	0.33 (0.49)	0.42 (0.52)
Urinary total hemoglobin (RBC·HPF-1)	Std. Seats	20.6 (12.6)	26.2 (11.9)	35.6 (33.0)	17.0 (10.1)	12.6 (12.4)	17.1 (8.7)	17.7 (6.0)
	Exp. Seats	24.5 (6.8)	18.8 (11.1)	17.6 (10.5)	19.2 (15.6)	19.0 (14.1)	18.0 (5.4)	11.9 (5.5)
	Total	22.5 (9.9)	22.1 (11.6)	26.6 (25.2)	18.1 (12.6)	15.8 (13.0)	17.6 (6.9)	14.8 (6.3)
Urinary free hemoglobin (mg·dL-1)	Std. Seats	0.051 (0.037)	0.054 (0.033)	0.060 (0.038)	0.047 (0.019)	0.037 (0.026)	0.034 (0.022)	0.041 (0.026)
	Exp. Seats	0.061 (0.019)	0.052 (0.025)	0.039 (0.024)	0.052 (0.031)	0.039 (0.027)	0.038 (0.026)	0.029 (0.018)
	Total	0.056 (0.028)	0.053 (0.027)	0.050 (0.032)	0.049 (0.025)	0.037 (0.025)	0.036 (0.023)	0.035 (0.022)

* Values shown are means (1 SD)

3. RESULTS

Table 2 shows the mean values (1 SD) for each of the urinary biochemistries at each sampling time for the 2 transit crews, and for the total sample.

4. DISCUSSION

4.1. Specific Gravity and Osmolality

Mean specific gravity and osmolality measurements were found to be within reference values (1.003 – 1.030, and, 50-1200 $mOsm \cdot kg^{-1}$, respectively) [10-12] for the entire measurement period. These values suggest that the subjects were reasonably well hydrated.

4.2. Albumin

Microalbuminuria is defined as having urine concentration of albumin between 20 and 200 $mg \cdot L^{-1}$. Clinical albuminuria is defined as a urine concentration > 200 $mg \cdot L^{-1}$ [13]. Several researchers have advocated adjusting the urinary albumin concentration for creatinine content as a way of adjusting for varying excretion rates and allowing the use of random urine samples for the determination of albuminuria [14]. Microalbuminuria using this approach is defined as a urinary concentration between 30 and 300 $mg_{albumin} \cdot g_{creatinine}^{-1}$ [15,16]. By either of these definitions, the average urinary albumin concentrations represent mild to moderate microalbuminuria for these SWCC that lasted for the entire measurement period.

The actual prevalence of microalbuminuria was 9/12 for the first morning, 11/11 on the evening of the first day's transit, 12/12 on the morning of the second transit day, 11/12 at the end of the second transit day, 10/10 on the first recovery morning, 12/12 on the first recovery evening, and 12/12 on the second recovery evening.

4.3. Total and Free Hemoglobin, Urine Color

The accepted reference value for microhematuria (total hemoglobin) is 3 $RBC \cdot HPF^{-1}$ [5,10]. No free hemoglobin is expected in the urine [10]. Based on this reference value, microhematuria was present on average throughout the transit. The actual prevalence of microhematuria was 12/12 for the first morning, 10/11 on the evening of the first day's transit, 11/12 on the morning of the second transit day, 10/12 at the end of the second transit day, 7/10 on the first recovery morning, 12/12 on the first recovery evening, and 12/12 on the second recovery evening. The color test for blood in the urine followed the same pattern as the hemoglobin values. There is no accepted reference value for this scale. However, the color test results were moderately correlated with both the total ($r^2 = 0.48$ across all samples) and the free ($r^2 = 0.37$) hemoglobin values, and is taken to be another indicator of blood and hemoglobin in the urine.

Alvarez and coworkers [7] measured microhematuria and microalbuminuria in 26 runners prior to, immediately following and 24-hours after completion of a 100-km race. They recorded microhematuria in 5 runners following the race, 2 of whom had shown such hematuria prior to the race. Microhematuria values immediately following this race were greater than average values seen during the transit in these SWCC (est. 39.3 vs. 22.0 $RBC \cdot HPF^{-1}$, ES = 0.56). However, initial values as well as those measured 24 hours after the race were less than those measured at comparable times in this study (9.9 vs. 22.6 $RBC \cdot HPF^{-1}$, Effect Size = -1.28, initially, and 11.6 vs. 17.6 $RBC \cdot HPF^{-1}$, Effect Size = -0.71, 24 hours after

the event for runners and SWCC, respectively). Clearly, there is a greater tonic value in this measure for the SWCC compared with these athletes. This finding may reflect the fact that Alvarez and coworkers studied responses to a discrete event, while we took measurements on individuals who had already experienced a set of training missions that may have affected the baseline (and transit) urinary blood/hemoglobin values.

Alvarez and coworkers also measured albumin in the urine prior to and following the 100-km race. The urinary albumin values recorded by Alvarez and coworkers are similar those seen during the transit in these SWCC (63.8 vs. 74.6 $mg \cdot dL^{-1}$ and 0.04 vs. 0.052 $mg_{albumin} \cdot mg_{creatinine}^{-1}$ for runners and SWCC, respectively).

McInnis and coworkers [8] measured hematuria and proteinuria at 5 minutes and 1 hour following three 60-second Wingate tests, a 60-minute treadmill run at 90% of anaerobic threshold, a 60-minute cycle ergometer ride at 90% of anaerobic threshold, and three 400-meter sprints. Of these only the sprints produced microhematuria on average. All ten subjects showed hematuria, unlike the other groups wherein only some of the subjects evidenced hematuria. The mean urinary hemoglobin was 6.5 (6.0) $RBC \cdot HPF^{-1}$, approximately one third the value seen during the Mk V transit of the present study.

In the McInnis study, performance of the Wingate tests resulted in a mean urinary protein value of 120 $mg \cdot L^{-1}$, the run, 150 $mg \cdot L^{-1}$, the bike, 30$mg \cdot L^{-1}$ and the sprints 890 (840) $mg \cdot L^{-1}$. If one assumes that "about half" of the urinary protein is albumin [12], the Wingate and run values are similar to those reported here for the transit. The urinary protein values following the bike exercise were much less that those reported here, and the sprints, a great deal more, possibly representing clinical proteinuria. Both the hematuria and proteinuria had decreased by about one third, 1 hour post exercise.

Helzer-Julin et al. [17] found similar hematuria ($\overline{X} = 4.54$ $RBC \cdot HPF^{-1}$) and proteinuria ($\overline{X} = 737.1$ $mg \cdot L^{-1}$) values to those of McInnis and coworkers in well-trained runners following two 60-minute runs at a 4 $min \cdot km^{-1}$ pace. Providing hydration during the run reduced the hematuria, but not the proteinuria. In these physically active subjects, proteinuria was present in the pre-exercise samples ($\overline{X} = 309.0$ $mg \cdot L^{-1}$), as it was in our SWCC samples. The hematuria of the runners was resolved within 48 hours of each exercise. The proteinuria returned to baseline values during the 48 hours between trials, but did not disappear during the study.

These references show that the magnitude of hematuria and albuminuria seen in our SWCC participants are within the range of values encountered during exercise training and athletic events. Unlike the reports of hematuria cited above, hematuria in the SWCC is not resolved in 48 hours, although the magnitude of the hemoglobin values is less for the last 3 samples than it is for the first 3 (see Table 2).

As was the case with the study of Helzer-Julin described above, we find chronically elevated urinary albumin values in our subjects. There is no significant trend for these values to decrease with time during our study ($F_{1,7} = 1.58$, $P = 0.25$). These albumin values are consistent with microalbuminuria, a common concomitant of exercise microhematuria. None of these SWCC reported past kidney problems on the Medical History Questionnaire that they filled out as part of the recruitment for this study (unpublished results). In a review of the records of a separate sample of 38 SWCC (unpublished data), no instances were found of a SWCC reporting with or being diagnosed with renal problems. At this time, it appears most likely that the hematuria and albuminuria seen in these SWCC is benign.

4.4. Creatinine

Mean creatinine remained within reference values (10 to 300 $mg \cdot dL^{-1}$, [11]) throughout the study. Urinary creatinine is a measure of relative clearance by the kidney. To calculate actual clearance values, blood

creatinine values would also have to be measured and the urine samples would have to be timed. The appearance of hemoglobin and red blood cells in the urine is thought, in part, a function of the increased glomerular filtration rate of the kidney. Increases in urinary creatinine values could also be a consequence of increased glomerular filtration rates. To investigate the degree of association between these sets of measures, study-wide correlations between creatinine and the measures of blood in the urine (color scale, free and total hemoglobin) were calculated. Squared correlation coefficients between urinary creatinine and urine color scale, total hemoglobin and free hemoglobin were 0.342, 0.347, and 0.566, respectively. These correlations are all significant ($P = 0.05$, 0.02, and 0.01, respectively) for a sample size of 12. The free hemoglobin values show the strongest association with creatinine excretion. Because of this moderate relationship between creatinine and the other hematuria indicators, creatinine was included in the evaluation of measures of intensity of shock exposure.

4.5. Transit effects

In order for these urinary measures to be useful as indicators of the magnitude of the mechanical shock received, these measures should be temporally related to the transit events. Based on the reports in the sports hematuria literature, one should expect the urinary blood/hemoglobin markers to be elevated during the transit and to decline during the recovery days following the transit. While the repeated-measures ANOVA did not reveal a significant effect of measurement time for any of the variables measured in this study, there were significant linear trends in the values for free hemoglobin ($F_{1,7} = 7.24$, $P = 0.03$) and color ($F_{1,7} = 7.24$, $P = 0.05$), and those for creatinine and total hemoglobin nearly achieved significance ($F_{1,7} = 4.53$, $P = 0.07$, and $F_{1,7} = 4.39$, $P = 0.08$, respectively). These statistics are based on the 9 subjects for whom there were complete data.

To create more stable indicators of these parameter values during the transit and the recovery period, urinary values for color, creatinine, free hemoglobin and total hemoglobin were averaged for the underway period (samples 2, 3, and 4), and the subsequent recovery period (samples 5, 6 and 7) for all the SWCC. Table 3 shows the comparison of these transit and recovery values. A one-tailed test was used because the available data on sports hematuria indicates that if the transit values differ from recovery, it will be because they are greater.

Table 3. Comparison of Transit and Recovery Values[1]

Variable	Transit	Recovery	t value[2]	Significance[3]
Urine color (scale value)	0.82 (0.42)	0.43 (0.35)	3.06	0.01
Creatinine ($mg \cdot dL^{-1}$)	166.7 (44.4)	134.8 (32.7)	2.43	0.02
Free hemoglobin ($mg \cdot dL^{-1}$)	0.050 (0.021)	0.037 (0.015)	2.11	0.03
Total hemoglobin ($RBC \cdot HPF^{-1}$)	22.0 (11.5)	15.9 (5.0)	1.96	0.04

[1]means (1 SD), $N = 12$
[2]*t*-test for correlated means, df = 11
[3]1-tailed, transit hypothesized to be greater

As can be seen from Table 3, the values for each indicator differed significantly between the transit period and the recovery period. It appears that these measures have value at the level of distinguishing periods of exposure from periods of no exposure. A better evaluation of the sensitivity of these measures might be achieved if we had been able to measure the actual exposure aboard both craft (see below).

4.6. Craft effects

To the extent that the shock-mounted seats attenuated the mechanical shock associated with the boat transit, one would expect the values of the hematuria markers to be less among those who crewed the boat with shock-mounted seats. However, attempts to measure differences in response between the 2 different craft were made difficult, not only by the small sample size, but also by the behavior of the two different crews. Anecdotal reports following the transit suggest that the 2 boats did not always run together, or at the same speeds. The boat with the standard seats could not always keep up with the one with the experimental seats, and when the 2 boats were running together, the boat with the standard seats apparently often ran in the wake of the boat with shock-mounted seats, decreasing the magnitude of the wave impacts. These reports suggest that there were differences in exposure on the 2 craft that were not related simply to the presence of experimental seats, and this may have confounded our attempts to assess differences in biochemical response to seat types.

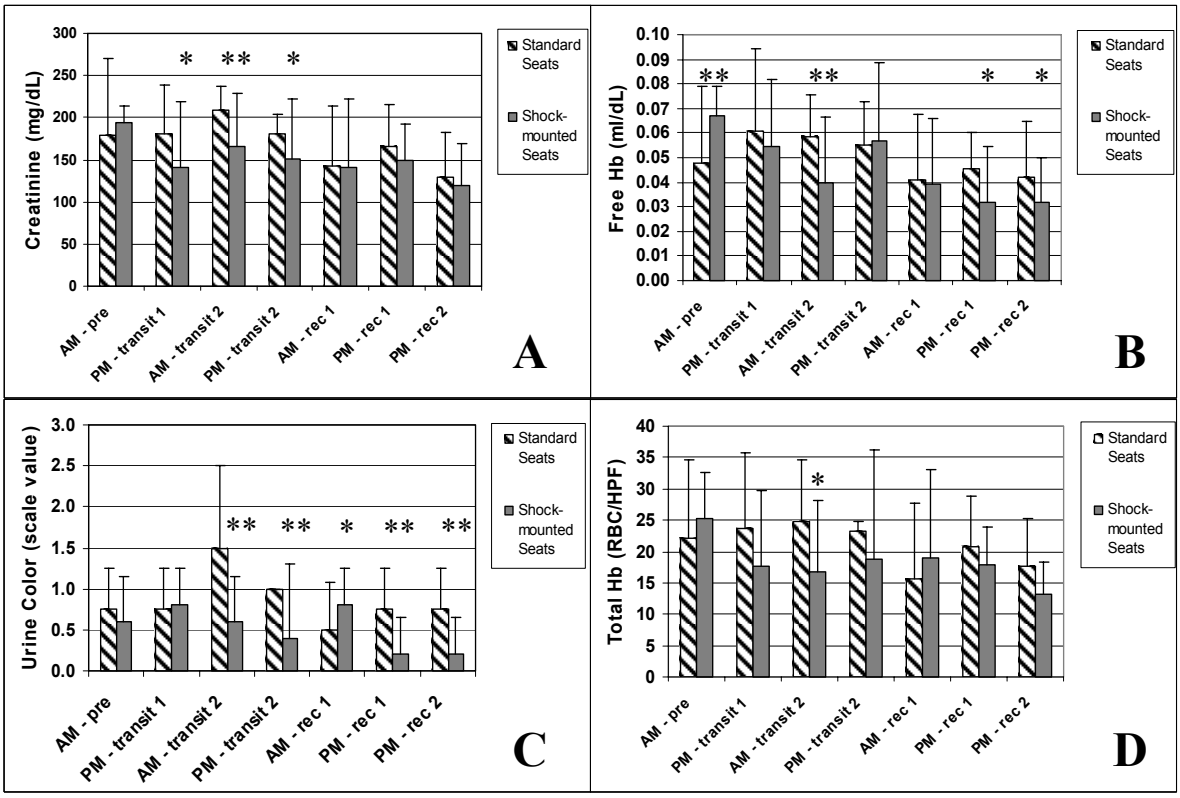

Figure 2. Urinary variables shown by sample time and craft. Panel A, urinary creatinine; Panel B, free hemoglobin; Panel C, urine color; and Panel D, total hemoglobin. Values represent only those subjects having complete data ($N = 9$, 4 from the standard-seat craft, 5 from the shock-mounted-seat craft). * Indicates a medium effect size for the difference between craft samples. ** Indicates a large effect size.

From the discussion of sports hematuria above, we would expect that the rougher the ride, the greater the level of hematuria [8,17,18]. The first day of the transit appeared to offer greater exposure to mechanical shock. The reported wave heights from buoys located along the route were greater for the first day (5-6 feet) than on the second day (3-4 feet). Further, the duration of the first day's transit was greater (13.5

hours vs. 9.0 hours) than that of the second day. For this reason, we would also expect the responses to the second day of transit to be less than those of the first day.

Figure 2 shows the measured values for creatinine, urine color, and free and total hemoglobin for each of the sampling periods. The values indicated by the bars differ from those listed in Table 3 in that they represent values from the 9 subjects for whom there were complete data (4 from the boat with the standard seats, 5 from the boat with shock-mounted seats). Only subjects with complete data were used to provide a consistent pattern of variances and avoid changes due to differing sample sizes.

The pre-transit values for these variables were, in general, already elevated, compared with the final recovery values. This likely reflects that these SWCC were training on boat operations prior during the week prior to the transit, and represent the effects of that training. A consistent trend in these urinary measures is for the crew of the craft with the standard seats to have greater values during the transit than the crew of the boat with the shock-mounted seats. Additionally, each of the variables has at least a medium effect size for the difference between craft for sample 3, taken on the morning following the first day of the transit. The magnitudes of the effect sizes are provided in Table 4.

Table 4. Effect Sizes for the Differences Between Craft Crews*

Sample Time	Creatinine	Urine Color	Total Hemoglobin	Free Hemoglobin
AM - pre-transit	0.25	0.28	-0.32	**-0.86**
PM - transit day 1	**0.56**	-0.11	0.49	0.21
AM - transit day 2	**0.84**	**1.15**	**0.75**	**0.80**
PM - transit day 2	**0.54**	**0.90**	0.35	-0.07
AM - recovery day 1	0.02	**-0.59**	-0.25	0.07
PM - recovery day 1	0.35	**1.17**	0.43	**0.70**
PM - recovery day 2	0.19	**1.17**	0.69	**0.51**

*Medium (0.5 – 0.79), and large (0.80 and above) effect sizes are indicated in boldface. A positive number indicates the value for the boat with the standard seats was greater than that for the boat with the shock-mounted seats.

The average effect size for the morning of transit day 2 was 0.89, a large effect. This effect size was based on a group size of 4.5, and has a power of much less than 0.5 [9]. In order to have a power of 0.8 for a one-tailed test, the group sample size would have to be increased to 17, all other things being equal. The situation could also be improved by better experimental control (starting from common baseline level of activity, ensuring that the boats all followed the same operational protocol), or more complete measurement of the exposure (allowing the response variables to be adjusted by any differences in exposure across situations). Under those conditions, adequate power might be achieved with smaller group sample sizes than 17.

5. CONCLUSIONS

From the results presented here, we conclude that there is a microhematuria associated with Mk V SOC operations. This hematuria appears to be similar in nature to that experienced by individuals carrying out activities involving repetitive bodily impact (such as running). The level of this hematuria appears to vary

with intensity of exposure, and there is a suggestion that with improved study designs subtle differences in exposure may be detected. While this suggestion remains to be proved, should the trends seen in this study be replicated, measurement of urinary variables related to modified kidney function may provide a basis for comparing mechanical shock exposures across different platforms and situations.

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7. DISCLAIMER

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Detailed Analysis or Short Description of the AVT-110 contributions and Question/Reply

The Questions/Answers listed in the next paragraphs (table) are limited to the written discussion forms received by the Technical Evaluator. The answers were normally given by the first mentioned author-speaker.

P28 J. Hodgton 'Biochemical Marker of Musculoskeletal Status During Small Craft Operations', (Naval HRC, US)

Microhematuria is a common consequence of high-impact exercise such as running and jumping. In order to determine whether or not a similar hematuria accompanies mechanical shock exposure associated with small boat operations in the open ocean, urinary variables were measured in two boat crews (total N = 12) during a 2-day Mk V Special Operations Craft transit down the eastern coast of the United States and a 2-day recovery period. The authors of this paper explained the details of their analysis: a paper that typically belongs to the category of Human Factors Engineering, with some observations on the influence of possible design modifications (physical ergonomical changes).

Discussor's name: N. Alem
Q. How do you explain the markers being lower at the end of the trip than the initial values?
R. The initial values represent the results of having engaged in small boat training during the week leading up to this study. It would appear that the training prior to the transit was more intense than the transit. Additionally the conditions on day 2 of the transit ware not as severe as on transit day 1.

Discussor's name: D. Sheridan
Q. Are follow-on experiments attempting to control crew behaviours, or include instrumentation, what may help achieve more comprehensive operating conditions?
R. In our actual work, we have instrumented all of the boats involved so that we will have direct measures of exposure for all crew members irrespective of differences in boat operations.

Discussor's name: L.P. Purtell
Q. Long- term damage?
R. Not observed. However, these are military personnel who will retire young enough that long-term kidney damage may be manifest.