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LAKEHEAD UNIVERSITY

THE INCIDENCE OF HEMATURIA WITH MIDDLE DISTANCE TRACK RUNNING INTERVAL TRAINING.

A THESIS PRESENTED TO

THE SCHOOL OF KINESIOLOGY, THE FACULTY OF ARTS AND SCIENCE, LAKEHEAD UNIVERSITY

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTERS OF APPLIED SPORTS
SCIENCE AND COACHING.

BY

GARETH R. JONES ©

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ABSTRACT

The purpose of this study was to answer the question, "Do middle distance track athletes experience hematuria with their normal competitive season interval workouts?" Secondary purposes were (1) to identify the type of workout most associated with hematuria as workouts were classified on the basis of intensity and duration and (2) compile supplementary measures associated with these workouts that would hopefully help to point towards a cause. The participants for this study were a group of seven male and three female (n=10), healthy, experienced middle distance runners aged 19-56 years who were all members of the Lakehead University Athletics Club in Thunder Bay, Ontario. Over the course of four weeks, subjects underwent urinalysis before and immediately following, their twice weekly interval sessions, over the course of a four week period. Pre-workout urine samples were examined for pH, specific gravity, and the presence of hematuria, proteinuria, and granular casts using reagent strip analysis. Positive hematuria samples precluded follow up analysis on that subject. Post workout urine samples underwent reagent strip analysis for pH, specific gravity, hematuria, and proteinuria. Positive specimens for hematuria were analysed under a microscope to calculate a more accurate red blood cell (RBC) and granular cast loss. Subjects were asked to provide follow-up samples until the reagent strip indicated a negative result for hematuria. Supplementary measures of 4min. peak blood lactate (pBLa), a subjective rating of perceived exertion (RPE), and the amount of time the subject worked above 65% of their VO_2max

(65%VO_2max) were used to indicate if a specific level of exertion was required to induce hematuria in middle distance track runners. Urine sampling indicated that middle distance track runners do experience hematuria, with nine of the ten subjects providing a positive sample at least once during the four week period. This study was unable to prove which of the thirteen workout classifications had the greatest incidence of hematuria because of the unequal number of subjects completing each workout classification. The results did demonutate that the greatest incidence of hematuria occurred following workouts of 800 m and 1500 m running pace with durations of 1001- 4000 m. The individual mean loss of red blood cells (RBC) per high power microscopic field (HPF) for the study group ranged between 2-81 RBC. All positive samples contained microcytic whole RBC. Protein and granular casts were observed regardless of the presence of RBC. A clear relationship between RBC loss and the supplementary measures of exertion was not observed.

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DEFINITIONS

Anaerobic Threshold (AT) - the work rate at which metabolic acidosis occurs and is associated with changes in respiratory gas exchange during a graded exercise test (Blair, Painter, Pate, Smith & Taylor, 1988). In this study it was identified as the point in which FEO_2 (Forced Expiratory Oxygen) increased without a linear increase in $FECO_2$ (Forced Expiratory Carbon-dioxide) during a VO_2max treadmill test (Appendix F).

Cast - masses of red blood cells moulded by the renal tubules, originating from the glomeruli. Abnormal microscopic blood in the urine composed of coagulated serum covered with red blood cells (Thomas, 1989).

Cystoscopic - microscopic examination of cells for the purpose of diagnosis (Thomas,1989).

Erythrocyte (RBC) - a red blood cell. One of the formed elements of peripheral blood(Miller & Keane, 1987).

Exertion - in this study, it will be identified as (1) the amount of work done above 65% of VO_2 max., (2) the rating of perceived exertion, and (3) the amount of accumulated blood lactate.

Glomerular filtration rate (GFR) - the amount of fluids passing through the kidney. The filtration rate is mainly dependent upon blood pressure in the glomeruli. The amount can vary depending on water intake, nature of diet, activity level, body temperature, age, and blood pressure (Thomas, 1989).

Glomerular filtration fraction (GFF) or renal filtration fraction (RFF) - represents the fraction of plasma in the glomeruli which is extruded through the glomerular membranes as filtrate. At rest FF = 0.2 and may increase by 15% during light exercise and 67% during heavy exercise (Castenfors, 1967).

Glomerulus - a small convoluted mass of capillaries in the kidney, which transfers blood and its waste products to the nephron (Miller & Keane, 1987).

Granular cast - the appearance of coarse and fine granular casts in urine sediment is generally considered to represent disintegration of the cellular casts remaining in the tubules as a result of urine stasis. Granular casts unrelated to cellular casts are sometimes seen following periods of stress and strenuous exercise and containing proteins and/or lysosomes (Strasinger, 1989).

Haptoglobin - a group of serum alpha$_2$ globulin glycoproteins that bind to free hemo-globin (Miller & Kean, 1987). It is increased in certain inflammatory conditions and decreased in hemolytic disorders (Thomas, 1989). Normal levels are .38 to 2.7 g/l (Harold et al., 1991).

Hematuria - the discharge of blood in the urine. The urine may be slightly blood tinged, grossly bloody, or a smoky brown colour (Kean & Miller, 1987). Normal findings in an average healthy population are 0 to 3 red blood cells/high power field (Harold et al., 1991).

Hemoglobin - a protein composed of four globular subunits, each bound to a single molecule of heme; the protein found in the red blood cells that gives them the ability to transport oxygen in the blood. Normal values are; men - 140-180 g/l, woman - 120-160 g/l (Harold et al., 1991).

Hemoglobinuria - presence of hemoglobin in the urine, but free from red blood cells. Occurs when hemoglobin from damaged red blood cells exceeds the binding ability of the blood protein haptoglobin (Thomas, 1989). Normally, hemoglobin is not found in the urine (Harold et al. 1991).

Hemolysis - the destruction of red blood cells with the liberation of hemoglobin, which diffuses into the fluid surrounding them (Thomas, 1989).

Hyaline - a translucent albuminoid substance obtainable from amyloid protein degeneration (Kean & Miller, 1987). The presence of 0 to 2 hyaline casts per low-power field is normal, as is the finding of increased numbers following strenuous exercise (Strainger,1989).

Intensity - in this study, refers to the individual running pace (400m, 800m, 1500m or 3000m) of the subject.

Lactic acid - an intermediate product of glucose metabolism and the end product of glycolysis, which provides energy anaerobically in skeletal muscle during heavy exercise (Kean & Miller, 1987). Normal resting values for whole blood lactate are 0.93 to 1.65 mmol (Harold et al.). In this thesis the concentration of whole blood lactate will be an indirect measure of exertion and blood lactate will refer to whole blood lactate.

Maximum Oxygen Uptake (VO_2max) - the highest oxygen uptake obtained for a given form of ergometery despite further increased work rate and effort. Characterized by a plateau of oxygen uptake despite further increases in work rate (Wasserman et al., 1987). In this study VO_2max as the highest VO_2 value obtained during the graded treadmill test.

Microscopic analysis - In this study results are reported as an average of 21 micoscopic fields examined. Red blood cells are reported as the number of cells per high power field (HPF x100) and granular casts are reported as the number of casts per low power field (LPF x40).

Myoglobinuria - myoglobin in the urine. It may occur following muscular activity, trauma, or as a result of a deficiency of the muscle enzyme phosphorylase (Thomas, 1989).

Nephron - the structural and functional unit of the kidney. Urine is formed by filtration in renal corpuscles, and selective reabsorption and secretion by cells of the renal tubule (Thomas, 1989).

Pace - for this study running pace will refer to a specific, target running pace assigned by the coach. The pace is based on past performance and reasonable performance expectations for the competition season.

Proteinuria - protein, usually albumin, in the urine (Thomas, 1989).

Pseudonephritis - a false indication of nephritis, which is an abnormal function of the kidney (Glanze, Anderson & Anderson, 1990). Used to describe temporary proteinuria and hematuria. In athletics it has been termed as "Athletic Pseudo nephritis" (Gardner, 1956).

Serum ferritin - a major iron storage protein found in reticuloendothelial cells and blood serum. It relates directly with the amount of iron stored in the body and can be accurately measured by radio immunoassay. Used to screen for iron deficiency or overload. Normal values: men - .20 to 3.0 micrograms/l, women - .20 to 1.2 micrograms/l (Harold et al. 1991).

CHAPTER 1

INTRODUCTION

Previous researchers have concluded that in controlled laboratory experiments hematuria can be produced after bouts of high intensity running (Kachadorian & Johnson, 1970; Helzer-Julin, Latin Mellion, Berg & Langan, 1988; Newhouse & McInnis, 1993). Mechanisms have been proposed that relate to the hemolysis of the red blood cell due to increased circulatory rate and higher body temperature (Yoshimura, 1970), the release of a hemolysing factor (Lindemann, Ekanger, Opstad, Nummestad & Josland, 1978), the compression of red blood cells by muscular activity, and with footstrike in activities such as running (Falsetti, Burke, Field, Frederick & Ratering, 1983; Miller, Pate & Burgess, 1988). The possibility also exists that red blood cells could be released in the urine following intense, physical exertion as a result of acute exercise acidosis and a diminished blood supply to the kidneys (Poortmans, 1984). Trauma to the bladder or kidney pelvis due to the jarring movement of running may also contribute to hematuria (Blacklock, 1977). If no underlying disease state exists, the potential result of chronic hematuria is iron deficiency, while more severe losses may be a sign of acute renal failure.

There is a gap in the literature as to the incidence of hematuria in middle distance track athletes during the course of their interval training. This study analysed the incidence and quantitative significance of hematuria amongst a

small population of middle distance trained track runners. Subjects were monitored for hematuria over a four week period of normal interval training. Urine samples were collected and analysed for the presence of hematuria following the completion of the workout. The information collected from this experiment may be beneficial in assessing and, if need be, controlling the incidence of hematuria in middle distance track runners.

Purpose

The primary purpose of this study was to answer the question," Do middle distance track athletes experience hematuria with their normal, competitive season, interval workouts?" Secondary purposes were to (1) identify the type of workout most associated with hematuria as workouts were classified on the basis of intensity and duration and (2) compile supplementary measures associated with these workouts that may help to point towards a cause.

Significance of Study

There is literature to suggest that middle distance runners may suffer from hematuria, yet no study has examined the incidence of hematuria in the practice environment. If the incidence is not significant, then it would be a relief to the track coach concerned about a potential route of iron loss. If the incidence was significant, further research would have to be done to ascertain the cause. The observation of hematuria following a variety of high intensity interval

sessions may help to identify those workouts which promote the loss of red blood cells and the supplementary measures may help to classify the levels of exertion which promote this disorder. A potential consequence of chronic hematuria is iron deficiency. Seiler, Nagel, Franz, Hellstern, Leitzmann and Jung (1989), reported that 25% of all iron loss in trained runners was attributed to hematuria. Therefore recommendations regarding the appropriate training required by track runners in order to prevent red blood cell loss and possible iron deficiency would hopefully be inferred from this study.

Hypothesis

It was hypothesized that the incidence of hematuria in middle distance runners will be significant during their normal, competitive season, interval training. Newhouse and McInnis (1993) found 100% of athletic individuals exhibited hematuria when subjected to a protocol involving 3 x 400 m all out sprints. The training of middle distance athletes entails some workouts of similar intensity and duration. In relevance to a secondary purpose, hematuria will be greatest following repeated running intervals at 800 m pace or faster with the cumulative duration being greater than 2000 m. An interval workout of this intensity and duration will likely cause sufficient hypoxic damage (Poortmans, 1984; Castenfors, 1977; Abarbanel, Benet, Lask, & Kimche, 1990) to the kidney and therefore induced red blood cell loss through hematuria. It may also be hypothesized that the hematuria produced during high intensity intervals will

involve the loss of intact red blood cells due to an increase in the glomerular filtration fraction (Newhouse & McInnis, 1993). It will also be expected that the supplementary measures (Table 1.) of exercise exertion, urinalysis and microscopic urinalysis will be consistent with the speculations noted above.

Table 1. Supplementary measures

Exercise Exertion	Urinalysis	Microscopic Urinalysis
Pre & post blood lactate	Pre & post urinary pH	Hematuria (>3 RBC per HPFx100)
Time above 65% VO_2max.	Pre & post specific gravity	Granular casts (per LPF x40)
Rating of perceived exertion	Proteinuria	

RBC: red blood cells; HPF: high power field; LPF: low power field.

Limitations

1. The analysis of heart rate, blood lactate, and urine was limited to the accuracy of measurement techniques and equipment. This study found that the reagent strips (Ames. Multistix 10 SG.) used for urinalysis were not reliable at reporting the extent of microcytic hematuria.
2. Microscopic analysis of the urine was limited to the subjective judgement of the laboratory technician.
3. The timing of urine collection was limited to the ability of subjects to provide samples.

4. The warm-down, immediately after the subject's final interval and before the 4 min. peak blood lactate sample, varied slightly.
5. The ability of the subject to run at their individual 400 m, 800 m, 1500 m and 3000 m pace rather than a pace that falls between or outside these target running paces.
6. Maximal oxygen consumption (VO_2max.) relies on the accuracy of the metabolic measurement cart and the subject's willingness to exert themselves to maximal exhaustion during the treadmill test.
7. The degree of bladder fullness for each subject was impossible to control with an empty bladder potentially contributing to the bladder trauma hypothesis for hematuria. Subjects were encouraged to arrive at their workouts well hydrated and to drink ad libitum from a nearby water fountain or from their personal drink bottles. Urine specific gravity measurements gave an indication of pre and post test hydration levels.
8. The workouts were limited to the discretion of the athlete and coach since the research objective was to impose a minimal impact on the normal training routine of the athletes. This limited the frequency of subject participation for each of the twenty possible intensity and duration workout combinations.

9. The athlete's diet was limited to the preference of the athlete, even though certain foods may change the urine colour to dark brown or red simulating gross macroscopic hematuria (Thompson. 1992).
10. Intra-individual and inter-individual comparisons were difficult to statistically analyse, forcing this study to use visual inspection to report marked changes as being significant (Kazdin, 1982).
11. An $\propto$level = 0.05 was set to show significance between variables.

Delimitations

1. The study was delimited to seven male and three female runners between the ages of 19 to 56 years. All runners were members of the Lakehead University Athletics Club, Thunder Bay, Ontario.
2. The only blood measurement was whole blood lactate which was collected prior to the workout and 4 minutes post exercise.
3. Urine was only tested for pH, specific gravity, hematuria, granular casts and proteinuria.
4. The type of running intervals and the duration was restricted to what the subjects had planned and what they actually did during the workout. The intensity of the intervals ranged from 400 m pace to 3000 m pace and the duration varied from 500 m to 5000 m.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Blood in the urine (hematuria), be it gross or microscopic, may be a sign of serious underlying disease (Strasinger, 1989). Hematuria observed in an athlete's urine may be due to a multitude of abnormal conditions such as cancer, urinary infections, medications, bladder/kidney trauma, foot strike hemolysis, or hypoxic damage to the nephron (Abarbanel, Benet, Lask & Kimche, 1990; Eichner, 1990). Gardner (1956) officially coined the term "*athletic pseudo-nephritis*" to describe exertion induced urine abnormalities in athletes. The major difference between athletic pseudo-nephritis and clinical nephritis is that with pseudo-nephritis the urine abnormalities resolve back to normal soon after the strenuous exercise bout. Track runners competing in 1,500 m races have been reported to produce urine following the race that is often loaded with red blood cells, protein and granular casts (Alyea & Parish, 1958). Athletes, coaches and sports medicine professionals should be aware of this condition as frequent high intensity and/or long duration workouts and competitions may promote the symptoms. Repeated red blood cell loss through the urine may be a contributing factor toward promoting anemic conditions in competitive athletes

Incidence of Hematuria

Microhematuria is quite prevalent in the general population and even more prevalent among athletes participating in strenuous sporting events (Eichner, 1990; Poortmans, 1984). In a study that examined the annual medical records of 100 asymptomatic servicemen over a 15 year period (12.2 visits per year), the cumulative incidence of microhematuria (more than three red blood cells per high power field) was 38% (Froom, Ribak & Benbassat, 1984). In another large population-based study by the Mayo Clinic, asymptomatic hematuria was found in 13% of adult males (35 years and up) with the same percentage found in postmenopausal women (aged 55 and up) (Mohr, Offord, Owen & Melton, 1986). A similar study by Mariani, Mariani, Machioni, Hariharan & Moriera (1989) at the Kaiser Medical Centre in Honolulu, found an incidence rate for hematuria of 15% in 1,346 medical students.

Running has been reported to result in microscopic hematuria. Siegel, Hennekens, Solomon and Van Boeckel (1979) obtained sequential urine specimens from a group of 50 male physicians before, immediately after, and on three successive days following a marathon race. While all pre race samples were normal, nine of the fifty (18%) post race urinalysis were positive for hematuria. Hematuria in marathoners has been reported to occur in 50% to 70% of the runners (Seiler, Nagel, Franz, Hellstern, Leitzmann & Jung, 1989; Dancaster & Whereat, 1971). Studies suggest that age is not a factor in predicting the incidence of hematuria, as it may occur in both children (Iitaka & West, 1978)

and adults. Greater incidences of hematuria have been reported in males but as more females participate in sport their numbers of reported cases continue to increase (Brieger, 1980).

Mechanisms of Exercise Induced Hematuria

Hematuria was first reported in 1713 when the Italian physician, Bernardini Ramazzini, observed bloody urine in runners which he attributed to the rupture of a small vein in the kidney (Buckle, 1965). In distance runners the most common explanation for hematuria has been reported to be foot strike hemolysis (Miller, Pate & Burgess, 1988) and/or bladder trauma (Boileau, 1980). According to Abarbanel et al. (1990), the longer and more strenuous the exercise, the more common and more prominent the hematuria. Karvonen and Saarela (1976), reported that frequent severe endurance training will cause the temporary decrease of hemoglobin due to the breaking up of erythrocytes and that this change may become permanent without adequate recovery. It has been speculated that exercise intensity may also increase the prevalence of hematuria (Kachadorian & Johnson, 1970). Kachadorian and Johnson (1970) found that as running speed increased, so then did the episodes of microscopic hematuria. Castenfors (1977), concluded that renal vasoconstriction and increased glomerular membrane permeability following exertion, were the main causes of sport related hematuria. Newhouse and McInnis (1993) found significant increases in hematuria and proteinuria following an interval running protocol of 3

x 400 m, with 1 min. recovery between repeats. This high intensity protocol caused 100% of the subjects to exhibit abnormal red blood cells loss in their first post workout urine sample. They concluded that intensity related changes to renal function were responsible for the abnormal condition. Physical exercise however, may contribute to hemolysis through other means. Models of how exercise related factors may be responsible for blood in the urine are presented in figures 2 and 3.

Foot strike hemolysis

Foot strike hemolysis is marked by a significant decrease in plasma haptoglobin (Hp) levels (Davidson, Robertson, Galea & Maughan, 1987; Dressendorfer, Wade & Frederick, 1992; Eichner, 1990; Eichner, 1985; Falsetti, Burke, Field, Frederick & Ratering, 1983; Horder & Horder, 1960; Miller et al., 1988). It is believed that during repeated foot strikes, there is trauma to the red blood cells circulating through the sole of the foot. This causes some red blood cells to rupture (Falsetti et al., 1983; Miller et al., 1988). If the hemolysis is slight, no hemoglobin (Hb) is lost in the urine as plasma Hp complexes with the free Hb and the complex is absorbed by hepatocytes. This HbHp-complex is too large to pass through the glomerulus. Significant hemolysis, however, can overload available Hp binding sites and the excess Hb is small enough to readily pass through the glomerular membrane. Most of the Hb appearing in the glomerular filtrate is reabsorbed in the proximal tubule, but if this capacity is exceeded, Hb is lost through the urine (Poortmans, 1977).

In support of this finding are the observations that running produces the lowest mean serum haptoglobin levels as compared with swimming, cycling, cross-country skiing, rowing, soccer and tennis (Blacklock, 1977). Similar results are observed between ultramarathoning vs. marathoning, downhill running vs. uphill running (Miller et al., 1988) and running in hard soled shoes vs. soft soled shoes (Dressendorfer et al., 1992; Falsetti et al., 1983). To the contrary, Newhouse & McInnis (1993) concluded that foot strike hemolysis may not be the primary cause of hematuria in some runners, but may be due to a change in renal function with high intensity exercise, resulting in the loss of whole red blood cells.

Ischemic and hypoxic damage of the renal vascular system

Exercise has been demonstrated to place severe stress on renal function (Fassett, Owen, Fairley, Birch & Fairley, 1982). During intense exercise blood is shunted to the working muscles and away from the splanchnic and renal vessels. During heavy work (above 65% of VO_2max.), almost 900 ml blood/min. may be shunted away from the kidneys to active muscles (Poortmans, 1984). Alyea and Parish (1958), reported that renal blood flow may drop from a normal 1,000 cc. per minute at rest to 200 cc. per minute during exercise. Exercise will also stimulate the sympathetic release of adrenalin and noradrenaline. These hormones mediate the renal vasoconstriction of the afferent and efferent glomerular arterioles. Alyea and Parish (1958) noted that adrenalin produced in

the absence of exercise will not cause urinary abnormalities. Moderate exercise will cause the glomerular filtration rate (GFR) and glomerular filtration fraction (GFF) to increase in order to compensate for the drop in renal blood flow and increased hydrostatic pressure (Alyea & Parish, 1958; Castenfors, 1977; Poortmans, 1984; Cainflocco, 1992). Severe exercise will decrease the GFR while the GFF will continue to increase (Figure 1) (Kachadorian & Johnson, 1970; Grimby, 1965). Poortmans, Labilloy, Niset and Sellier (1981) suggested that post exercise proteinuria was a result of increased glomerular permeability and a saturation of the tubular reabsorption.

The incidence of hematuria is greater following events that require high oxygen uptake (Hoover & Cromie, 1984). Poortmans et al. (1981) studied 15 men who performed different running tests (100 m to 3000 m) at maximal speed and observed that post exercise proteinuria related ($r=0.87$) to formed lactate rather than exercise duration. Helzer-Julin, Latin, Mellion, Berg and Langan (1988) reported that exercise intensity and dehydration were significant factors in producing increases in proteinuria and hematuria. Newhouse and McInnis (1993) who observed intact red blood cells in the urine after high intensity interval runs, found exercise intensity to be a significant factor ($P \leq 0.05$) in producing increases in proteinuria and hematuria.

The shunting of blood away from the kidneys through renal vasoconstriction can cause hypoxic damage to the nephron and increased glomerular permeability, thereby allowing the increased urinary excretion of

proteins and erythrocytes (Abarbanel et al., 1990; Castenfors, 1977; Poortmans, 1984). Physical exercise has been shown to diminish blood supply to the renal vascular system during exercise (Poortmans, 1984). Baker (1959) reported that the spiral arteriole vessels at the renal papilla, are starved of oxygen during excessive physical stress. These spiral vessels connect the interlobular arteries to the capillary bed surrounding the minor calyx. The increased renal vascular resistance as a result of their spiral structure and the drop in plasma flow will decrease the oxygen supply and increase the fragility of these vessels. When the renal blood supply returns to normal these vessels may shed red blood cells directly into the minor calyces for excretion. Hoover and Cromie (1984) commented that Baker's theory would explain why red blood cell casts are less likely in intensity related hematuria, while protein and hyaline casts are found with free red blood cells. It was also reported by Baker (1959), that children may not experience this type of hypoxic based hematuria as readily as adults, since the spiral arteriole vessels become more twisted with age.

The hypoxic mediated type of hematuria may be differentiated from hematuria due to foot strike hemolysis. The foot strike mechanism will lead to hemoglobinuria and/or myoglobinuria, while hypoxic damage may result in the loss of intact red blood cells (Abarbanel et al., 1990). Another difference between the two mechanisms is that hypoxic damage is more intensity related while foot strike hemolysis is more duration related. Alyea and Parish (1958) reported that the degree of physical stress was not as significant as the duration of sustained

exercise at increasing urinary red blood cell, protein and granular cast loss, although both factors were important. Events that combine both high intensity and long duration would thus have the greatest association with hematuria. Proof of this is seen in the study by Alyea and Parish (1958) where middle distance track runners and 1,500 m swimmers had the greatest loss of albumin, red blood cells and granular casts, when compared with sprinters, rowers, lacrosse players and football players who also exhibited similar urinary findings but not quite as severe.

According to Thompson (1989) red blood cells may enter the urine at any point along the urinary tract from the glomerulus to the distal urethra. Cells that enter the urine at the level of the glomerulus are typically dysmorphic in appearance; the cell membranes appear wrinkled and irregular, and the cells vary in size. By contrast, red blood cells that originate from sites distal to the glomerulus are more often uniform in size and shape. Fassett, Horgan and Mathew (1982) suggested criteria that if more than 80% of the red blood cells in the urine are dysmorphic then the condition should be termed *glomerular hematuria* and when more than 80% of the red cells are undistorted then the condition should be reported as *non glomerular.*

The hypoxia experienced with very severe exercise, may damage the kidneys through the elevated concentration of lactic acid. This acidotic insult may cause an increased permeability of the intercellular wall (Javitt & Miller, 1952).

The presence of a hemolysing factor with exercise

Researchers have shown that persons who are repeatedly exposed to prolonged severe exercise, demonstrate an increased turnover and reduced half life of red blood cells (Refsum, Jordfald & Stromme, 1976). Shiraki, Yoshimura and Yamada (1974) reported that during exercise there is an increased destruction of erythrocytes due to the liberation of a hemolysing factor (lysolecithin). Strenuous exercise promotes adrenalin secretion that causes the spleen to contract, releasing lysolecithin into the circulating blood. Increased cell fragility has also been linked to the release of catecholamines (Lindemann, Ekanger, Opstad & Nummestad, 1978). Nevertheless, this may again be ultimately due to lysolecithin, as adrenalin stimulates the contraction of the spleen (Yoshimura, 1970). Shiraki et al. (1974) theorized that the adrenalin mediated contraction of the spleen, as a result of severe bouts of exercise and may lead to the release of a hemolysing factor that may predispose red blood cells to increased osmotic and mechanical fragility. Yoshimura (1970) noted that the hemolysis observed with exercise may be an adaptive response, because the released hemoglobin from rat erythrocyte cells were reutilized rapidly to promote the growth of muscle protein and new erythrocytes.

Bladder and kidney trauma

Bloody urine in some male runners may be caused by the impact of the posterior bladder wall against the bladder case, causing vascular lesions

(Abarbanel et al., 1990; Blacklock, 1977). Blacklock (1977) reported eight-such cases in a study of 18 long distance runners with hematuria. Cystoscopic examination of these athletes showed bladder contusions within 48 hours after runs of 10,000 m or more. This type of bleeding appeared to be more prevalent in men than women, which may be due to the fact that the bladder outlet anatomy differs (Shiraki et al., 1974).

Direct trauma to the kidney, as experienced with contact sports such as boxing, lacrosse and football may also be a possible cause of hematuria. Alyea and Parish (1958) reported that athletes who are involved in contact sports such as football, lacrosse and boxing may endure enough trauma to increase the actual number of red blood cells in the urine to cause gross hematuria. Gardner (1956) reported a 45% incidence of hematuria from 424 urine samples taken after games and practices from 47 football players. Similar findings have been observed with boxers where over half the competitors voided blood after completing their fights. An explanation for this anomaly may be directed towards the lack of perirenal fat and the crouched body position of the boxers in question (Kleinman, 1958).

The kidneys may also endure mechanical trauma from the repetitive jarring action of long distance running. This repetitive action may provoke the kidneys to descend, causing the renal vein to kink at the junction of the inferior vena cava (Reiss, 1979). Kinking of the renal vein would elevate renal vein pressure resulting in an increase in the RFF. To eliminate the possibility of

permanent damage or disease, follow up samples should be taken 24 to 72 hours following the event to ensure that the urine returns to normal.

Drug induced hematuria

The use of non-steroidal anti-inflammatory drugs (NSAIDS) can induce hematuria (Eichner, 1990; Kraus, Siroky, Babayan & Krane, 1988; Vane, 1978). Non-steroidal anti-inflammatory drugs are frequently used in athletics for the treatment of injuries. In a study of patients with asymptomatic hematuria, 54% were taking NSAIDS (Kraus et al., 1988). It has been established that NSAIDS such as aspirin, ibuprofen and fenoprofen, interfere with platelet function through the inhibition of cyclo-oxygenase; an enzyme that generates thromboxane A2 from arachidonic acid obstructing platelet adhesiveness and aggregation (Vane, 1978). These anti-inflammatory drugs also interfere with the release of the prostoglandin, prostacyclin, from the glomeruli. The release of prostacyclin acts as a compensatory mechanism against renal vasoconstriction. Non-steroidal anti-inflammatory drugs inhibit the release of this modulatory prostoglandin causing increased blood pressure (a 5-10 mm Hg increase) and possible renal failure (Wendland, Wagoner & Holley, 1980). Non-steroidal anti-inflammatory drugs have also been implicated with papillary necrosis (Wiseman & Reinhart, 1975). Identification of those patients who are likely to suffer hemorrhagic complications due to the NSAIDS is virtually impossible (Kraus et al., 1988).

Hydration and hematuria

During prolonged strenuous exercise, excessive water loss may be related to hematuria. Helzer-Julin et al. (1988) suggested that a relationship between hydration and hematuria and proteinuria may exist. They found that mild dehydration had a significant effect ($p \leq 0.06$ level) in producing increases in post exercise hematuria but not proteinuria. Reiss (1979) states that transient dehydration occurring during sustained exercise will produce a lower glomerular filtration rate that could aggravate further the already depressed renal system. Clement and Sawchuck (1984) remarked that increased blood viscosity and increased intra erythrocytic osmolarity as well as blood plasma osmolarity and acute post exercise acidosis may accelerate the hemolysis of older erythrocytes. This concept may have some merit when one considers that erythrocytes are destroyed whenever they are exposed to solutions that are not isotonic to blood plasma. A high body temperature will result in a hyper osmotic plasma environment through dehydration. This environment will cause erythrocyte cells to become hypohydrated and undergo lysis (Rhoades & Saunders, 1992).

Increased circulation rate

It has been speculated that red blood cell membrane resistance may be weakened by the increased circulation rate attributed to strenuous work. These conditions cause greater wear and tear on the red blood cells fragile membranes.

This repeated action will eventually result in their hemolysis (Yoshimura, 1970; Clement & Sawchuck, 1984).

Muscular tissue damage

Extreme physical exertion will impair the sodium-calcium exchange across the muscle cell membrane causing the calcium ion concentration within the cell to increase to a destructive level (Milne, 1988). As muscle membranes are ruptured the cell contents, such as myoglobin and creatine phosphokinase, are released into the blood stream (Schiff, Macsearraigh & Kallmeyer, 1978). The serum creatinine kinase level does not bear a direct relationship to the development or the degree of renal failure (Schulze, 1982) although the associated release of myoglobin into the blood stream is believed to have a toxic effect on the kidneys (Refusum et al., 1976). Myoglobin along with the compounding effects of dehydration, hypovolemia and acidosis may impede or halt the excretory and metabolic functions of the kidney (Milne, 1988).

Myoglobinuria may easily be misdiagnosed as hematuria as both abnormalities occur under similar conditions. Microscopic analysis should be utilized as the preferred diagnostic tool to differentiate between the two conditions as myoglobin may produce a false-positive reagent strip test for blood (Strasinger, 1989).

Peroxidation of the red blood cell membrane

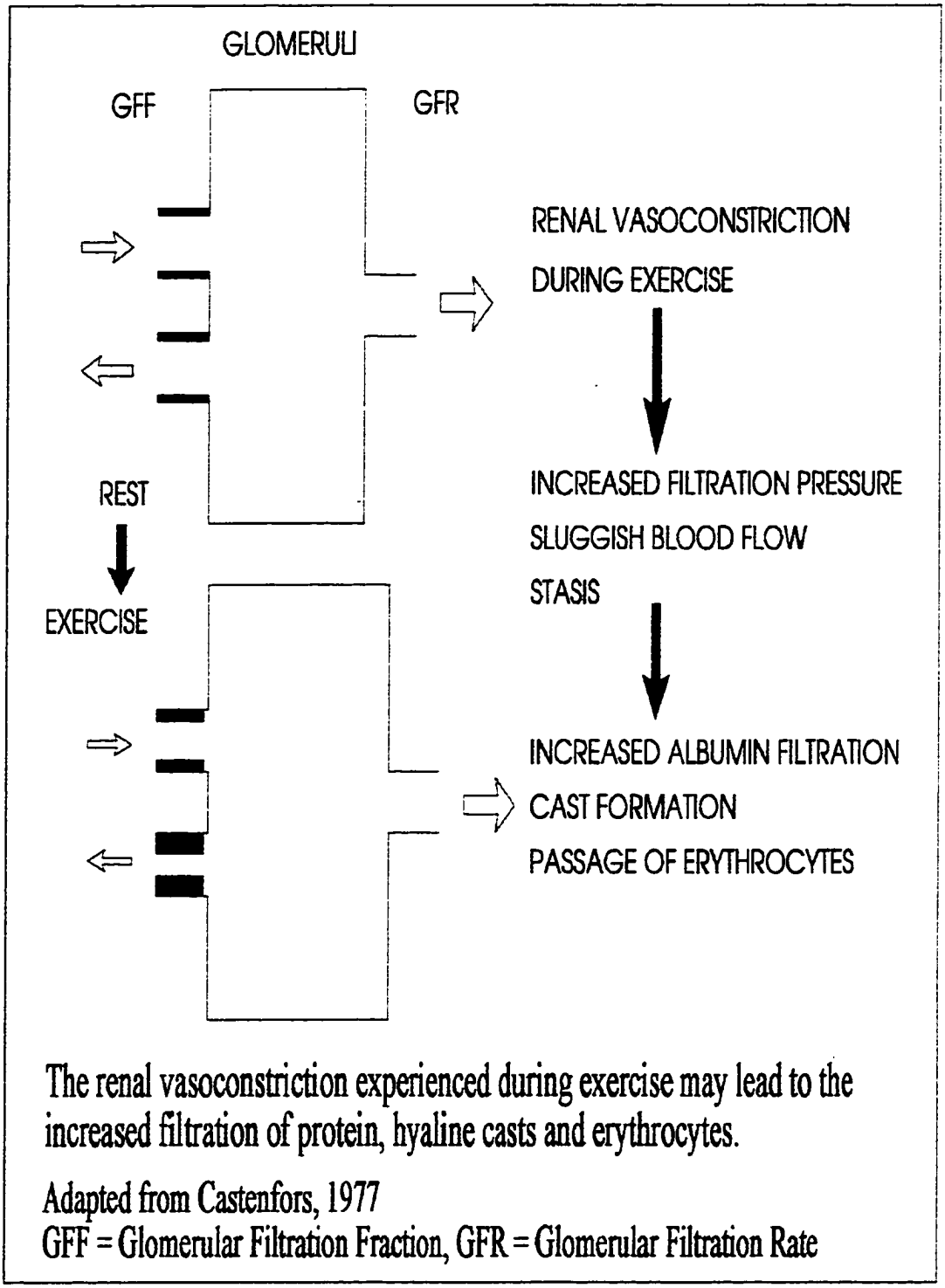
Exhaustive maximal exercise induces the production of oxygen intermediates (free radicals) in large quantities (Sjodin, Westing & Apple, 1990). Free radicals induce peroxidation of unsaturated fatty acids in membrane phospholipids and polymerisation of membrane proteins (Zbigniew, 1990). These free radicals therefore may play a role in organ tissue damage, including the kidney (Refsum et al., 1976) and in damage to the red blood cell membrane (Chien, 1987). Peroxidation may result in increased red blood cell hemolysis and also the altering of kidney function (Refsum et al., 1976).

Summary

Research has revealed an increased prevalence of hematuria in athletes, with some research suggesting that track runners who train and race at high running intensities could be at risk. The mechanisms responsible may be traced to different sources or a combination thereof. Foot strike hemolysis, hypoxic damage to the kidneys, the release of a hemolysing factor, renal ischemia, bladder trauma, dehydration, NSAIDS and/or muscle tissue damage have all been shown to contribute to the loss of hemoglobin or whole red blood cells through the urine. Several researchers (Newhouse & McInnis, 1993; Poortmans, 1981; Abarbanel et al., 1990; Kachadorian & Johnson, 1970) have reported that exercise intensity may have a significant effect on hypoxic damage to the kidneys. Reiss (1979) commented that in most instances urine abnormalities correlate to the degree of

stress endured as symptoms increase with duration or intensity of effort. The extreme efforts put forth by an athlete during practice or competition over 10,000 m may precipitate trauma to the empty bladder. While hematuria has been documented under various experimental exercise conditions, no study has yet examined the incidence of hematuria under the stress of a normal, competitive season, middle distance interval training.

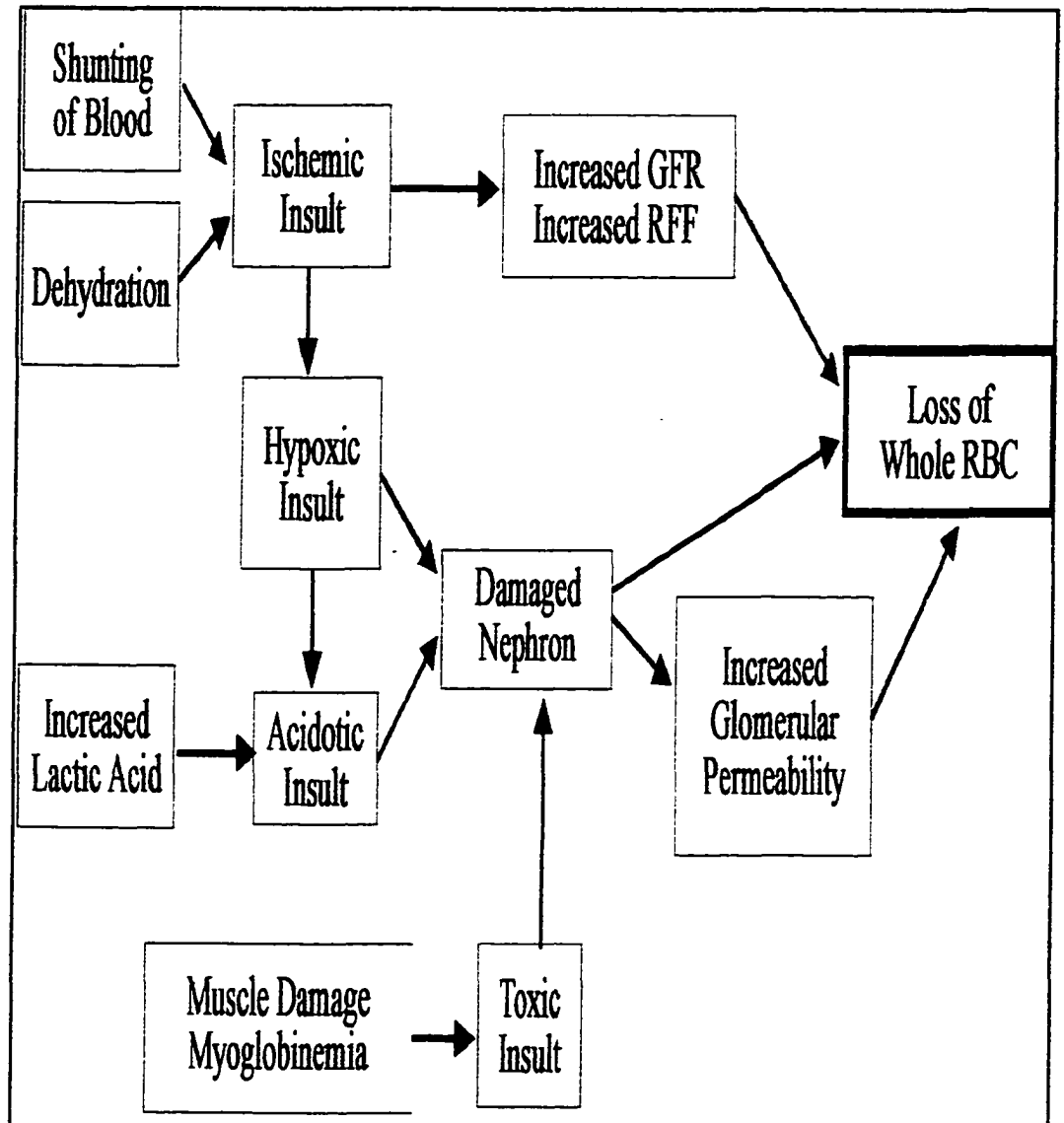
Figure 1. Glomerular Filtration with Exercise



The renal vasoconstriction experienced during exercise may lead to the increased filtration of protein, hyaline casts and erythrocytes.

Adapted from Castenfors, 1977
GFF = Glomerular Filtration Fraction, GFR = Glomerular Filtration Rate

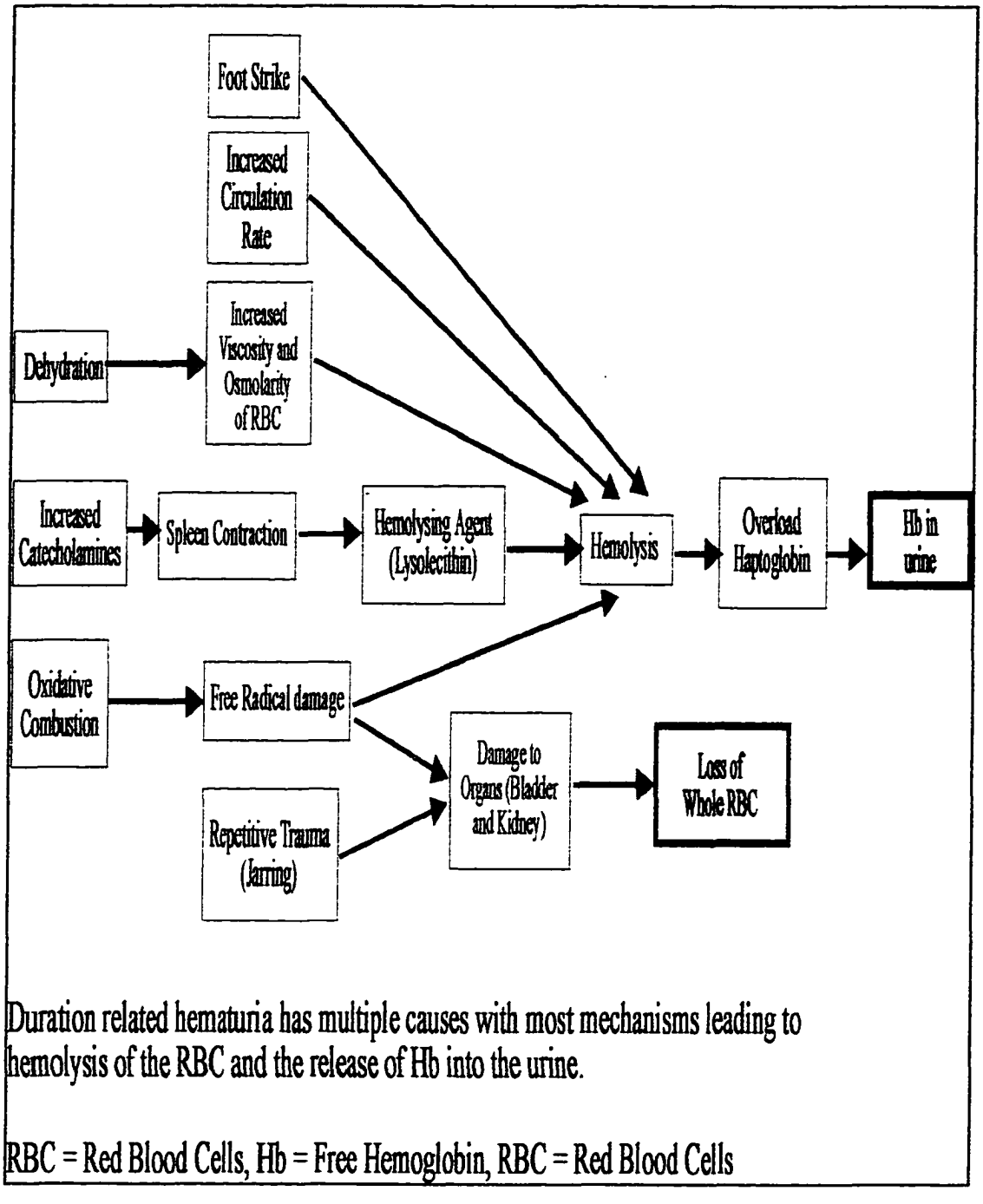
Figure 2. Intensity related mechanisms of hematuria



Intensity related hematuria is likely the result of multiple insults to the kidneys with the end consequence being whole RBC in the urine.

RFF = Renal Filtration Fraction, GFR = Glomerular Filtration Rate, RBC = Red Blood Cells

Figure 3. Duration related mechanisms of Hematuria



CHAPTER 3

METHODOLOGY

Subjects

The subject pool included seven male and three female, healthy, middle distance runners of good athletic ability, from the Lakehead University Athletics Club in Thunder Bay, Ontario. Their ages ranged between 19 to 56 years and all were non-smokers. According to Hoover and Cromie (1981) age is not a major factor in causing exercise related hematuria. All subjects gave written informed consent prior to the study. Two of the female runners were excluded from the study on two of the testing days, due to positive pre-test urinalysis for blood. Their positive urine samples were a result of menstruation. The subjects were specifically asked to report if they were taking non-steroidal anti-inflammatory drugs during the four week testing period.

Criteria for exclusion from the study

The exclusion criteria for this study included those subjects who:

1. exhibited a positive result for hematuria on any pre-test sample which could not be attributed to menstruation. When menstruation was a factor only the data on that day was excluded.
2. were unexperienced at running at their pre-set intensities.

3. were unable to complete a treadmill VO_2 max test.
4. produced a resting blood lactate sample of greater than 4 mmol/L.
5. were taking NSAIDs during the four week testing period.

Methods

Over a four week period during an indoor track competitive season, subjects were tested two times per week on their interval training days (Tuesdays & Thursdays, 4:30-6:30 pm). All interval runs were performed on a 167 m banked, rubberized, indoor running track at the Confederation College, Thunder Bay, Ontario.

VO_2 Max. Protocol

All subjects underwent an incremental $V0_2$max test with workload increasing every minute (Appendix F) conducted at the Human Performance Laboratory at Lakehead University. Descriptive information on individual VO_2max., AT, maximum heart rate, heart rate at 65% of $V0_2$ max., pre and 4 minute post blood lactates, and pre and post urine samples were collected. The subject's height and weight were determined, with height being measured to the nearest 0.5 centimetres and weight to the nearest 0.1 kilogram. The results from the running treadmill test were used to determine individual $V0_2$max and anaerobic threshold (AT). Anaerobic threshold was identified as the point at

which FEO_2 increased without a linear increase in $FECO_2$. This data was used to describe the population and provide comparative scores for the field tests.

Urinalysis

Baseline urine samples and resting blood lactate samples were taken prior to each interval workout. Baseline urine samples were screened for hematuria that was not attributed to the training session, such as any underlying disease or female menses. The first 10-15 ml urine sample was obtained following the interval workout and was analysed for hematuria, specific gravity, and pH using reagent strips (Ames Multistix 10 SG: Miles Canada Inc.). Reports have shown that reagent strip analysis has a 97.5% sensitivity and specificity for the detection of hematuria (Mee & McAninch, 1989).

The reagent strip reaction for blood utilizes the pseudo peroxide activity of hemoglobin to catalyse a reaction between hydrogen peroxide and the chromogen tetramethylbenzidine to produce an oxidized chromogen which has a green colour (Strasinger, 1989). Free hemoglobin produces a uniform colour change on the reagent pad from negative yellow through to strongly positive blue. In contrast, intact RBC are lysed as they come in contact with the pad and the liberated hemoglobin results in a speckled pattern on the pad with the degree of hematuria estimated by the intensity of the pattern. Urine sampling continued with each emptying of the bladder until the reagent strip indicated a negative

result for hematuria. Positive samples were refrigerated and transported to Saint Joseph's General Hospital, Thunder Bay, Ontario for microscopic evaluation.

Positive samples were spun at 2,000 revolutions per minute for five minutes in a centrifuge (Centra CL4). They were then retested with a freshly dipped reagent strip which was then placed in a urine chemistry analyser (Ames CLINTEK 200^{+}: Miles Canada Inc.) and analysed for the presence of leukocytes, nitrates, urobilinogen, protein, pH, blood, specific gravity, ketones, bilirubin, and glucose. A drop of the sample's sediment was then placed on a glass slide for microscopic examination.

Microscopic analysis

Under a low-power microscopic field (40x) the sample was analysed for the presence of granular and hyaline casts as the average number after scanning 21 fields. The sample was then analysed under a high-power field (100x) for hemolysised and whole RBC as an average of 21 fields. It is commonly accepted that greater than 3 red blood cells per high power field or 1000 RBC/ml of urine is above the normal range (Eichner, 1990; Thompson, 1989).

Microscopic analysis also confirmed the reagent strips reliability as certain factors may produce false positive or false negative reagent strip results. A false positive result may be caused by vegetable peroxide, bacterial enzymes (*Escherichia cloi*) or the presence of myoglobin in the urine sample. A false negative reaction may be casued by a high urinary ascorbic acid level, a high

urinary nitrate level, or a urine pH below 5.0. These three factors may inhibit RBC hemolysis on the reagent strip. To rule out the false negative test possibility, all post workout urine samples underwent microscopic analysis on two separate occasions. This was done regardless of the reagent strip reading. This would help to rule out the possibility of a false positive or false negative reagent strip reaction interfering with the results.

Blood lactate

The level of blood lactate has been shown to be highly correlated with relative intensity or effort of exercise (Jacobs,1986; Janssen, 1987) and therefore provides a sound method of measuring the effort put forth by the subject. Blood lactate sampling was performed prior to each test to ensure that the subject was rested and that no previous strenuous exercise would contribute to the 4 minute post blood lactate values observed in each test. A second blood lactate sample was taken 4 minutes post-test, following the final interval of the workout in order to record peak values (Ohkuwa, Kato, Katsumata, Nakao, Miyamura, 1984). With regards to the production of peak blood lactate between the sexes, Mader, Heck, Fohrenbach and Hollmann, (1979), found no difference between male and female middle distance runners. Blood lactate samples were analysed on site with a portable blood lactate analyser (model # 1500, Yellow Spring Instruments) which was calibrated with 5 mmol/L standardized lactate solution prior to testing and following each analysis of five blood lactate samples. The lactate analyser was

flushed clean with double distilled water following calibration and after each subsequent sample analysis to ensure accurate readings.

Rating of perceived exertion

A subjective scale of perceived exertion (RPE: Borg, 10-pt. scale, 1982) (Appendix E) was also included as a second measure of the intensity level achieved. The RPE was based on the total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. The use of the RPE scale for arms and legs has been demonstrated to be positively related to blood pH (Robertson et al., 1985). In order to prevent the influence of blood lactate results on the subjects RPE, scores were recorded before the lactate samples were analysed. Following these measures the subjects were then allowed to continue with their warm-down.

Time above 65% of VO_2 Max.

Exercise heart rates were recorded with the Polar Vantage XL heart rate monitor (Polar INC.) every 15 sec. for each of the subject's interval workouts. Heart rates were plotted with a heart rate analysis software program (POLAR INC.). The percent of total workout time spent above 65% of the individual $V0_2max$. was calculated and used as another indication of effort. Work done at or above 65% of VO_2max may indicate hypoxic conditions within the kidney (Poortmans, 1984).

Workout groupings

To ensure that the data collection did not interfere with the specific training routine of the individual athletes, a variety of workout groupings were designed depending on the intensity and duration of the workout. Intensity was dictated by the athlete's individual race pace for 400 m, 800 m, 1500 m, and 3000 m. The duration was a measure of the distance travelled by the athlete during the interval workout (warm-up and recovery jogs were not included) and ranged between a minimum of 200 m to a maximum of 5000 m. Duration was dependent on the subject's running pace, athletic ability on the testing day, and the scheduled workout (Appendix B). Therefore, workouts of higher intensity and substantial duration (number of interval repetitions) would achieve elevated levels of blood lactate (Balsom, Seger, Sjodin, Ekblom 1992; Janssen, 1986), higher ratings of perceived exertion (Borg, 1982), and a greater percentage of the workout would be done above 65% of $V0_2max$.

Training log

Each subject kept a detailed training log (Appendix C) so that outside influences (i.e. other types of training, female menstruation cycles, type of running shoe used, medication taken, personal wellness, etc.) would be reported and analysed. Females that had their menstrual period during one of the test days were omitted from testing until menstruation ceased.

Design of the Study

This study used descriptive statistics to illustrate whether middle distance track athletes experienced hematuria with their normal, competitive season, interval workouts. No experimental control was placed upon the workouts as this study did not want to interfere with the athlete's normal training routine as they prepared for important track meets. Classifying each workout by intensity and duration would allow the study to illustrate the workouts completed by the athletes which were most associated with hematuria. Each individual's workouts underwent visual inspection (Kazdin, 1982), to observe whether a relationship existed between the supplementary measures and hematuria. Visual inspection of these measures in regards to changes in means, levels, trends, and latency of change, for each individual subject would help establish a cause (Kazdin, 1982). Pearson product-moment correlations were performed on all variables with the criterion level of significance set at $P \leq 0.05$.

CHAPTER 4

RESULTS

The subjects in this study had an average age of 26.1 ± 11.9 years (Mean ± SD) (Table 2). The average weight and height was 68.75 ± 8.5 kg and 177.69 ± 8.52 cm, respectively. All of the subjects were in good general health and did not report any history of renal or bladder disease. They were all experienced middle distance runners with an average maximum aerobic power of 57.5 ml/kg/min, an average anaerobic threshold of 49.8 ml/kg/min, and an average maximum heart rate of 194 beats per minute. Additional descriptive data can be seen in Table 2.

None of the male subjects were taking any medication during the test. One female subject was taking daily doses of 400 mg and 1000 mg of vitamins E and C respectively, while another female subject was taking 300 mg of nova-ferrous gluconate daily. The literature (Strasinger, 1989) states that high levels of ascorbic acid may produce a false-negative on the reagent strip for hematuria. This never occurred and seven of her eight samples underwent microscopic analysis for hematuria. The third female subject was free of medication. Two female subjects provided pre-test positive urinalysis results for blood due to menstruation. Their results were excluded from the study on those particular days.

Table 2. Characteristics of the subjects (n=10) who participated.

	Mean	S.D.	RANGE	
Age (years)	26.19	11.9	19.0	56.0
Weight (kg)	68.75	8.5	57.7	81.5
Height (cm)	177.69	8.5	156.0	186.0
$V0_2max$ (ml/kg/min)	57.49	6.9	48.6	71.2
AT (ml/kg/min)	49.77	4.9	43.8	58.2
Heart Rate max (bpm)	193.5	7.7	180.0	205.0

Values shown are Mean. ± SD. Range. AT.: anaerobic threshold.

None of the subjects exhibited macroscopic (visible) hematuria but nine out of ten (90%) of the subjects experienced hematuria (>3 RBC per HPF) immediately following at least one of their interval workouts. Taking into account every trial for each subject, 45% (31 out of 69) of the completed workouts exhibited hematuria (>3 per HPF) and 13% (9 out of 69) suffered maximal red blood cell loss (>100 per HPF or > 33 000 rbc/ ml of urine). One of the data collection trials included a track race in which four subjects competed (three at 1500 m and one at 3000 m). The four subjects (2 males and 2 females) all exhibited hematuria and two subjects (both males) had maximal red blood cell loss of > 100 per HPF.

Microscopic analysis revealed that all urine samples that tested positive for hematuria contained whole RBC rather than hemolysed RBC. This finding eliminated the possibility of foot strike hemolysis. Initial post-workout urine

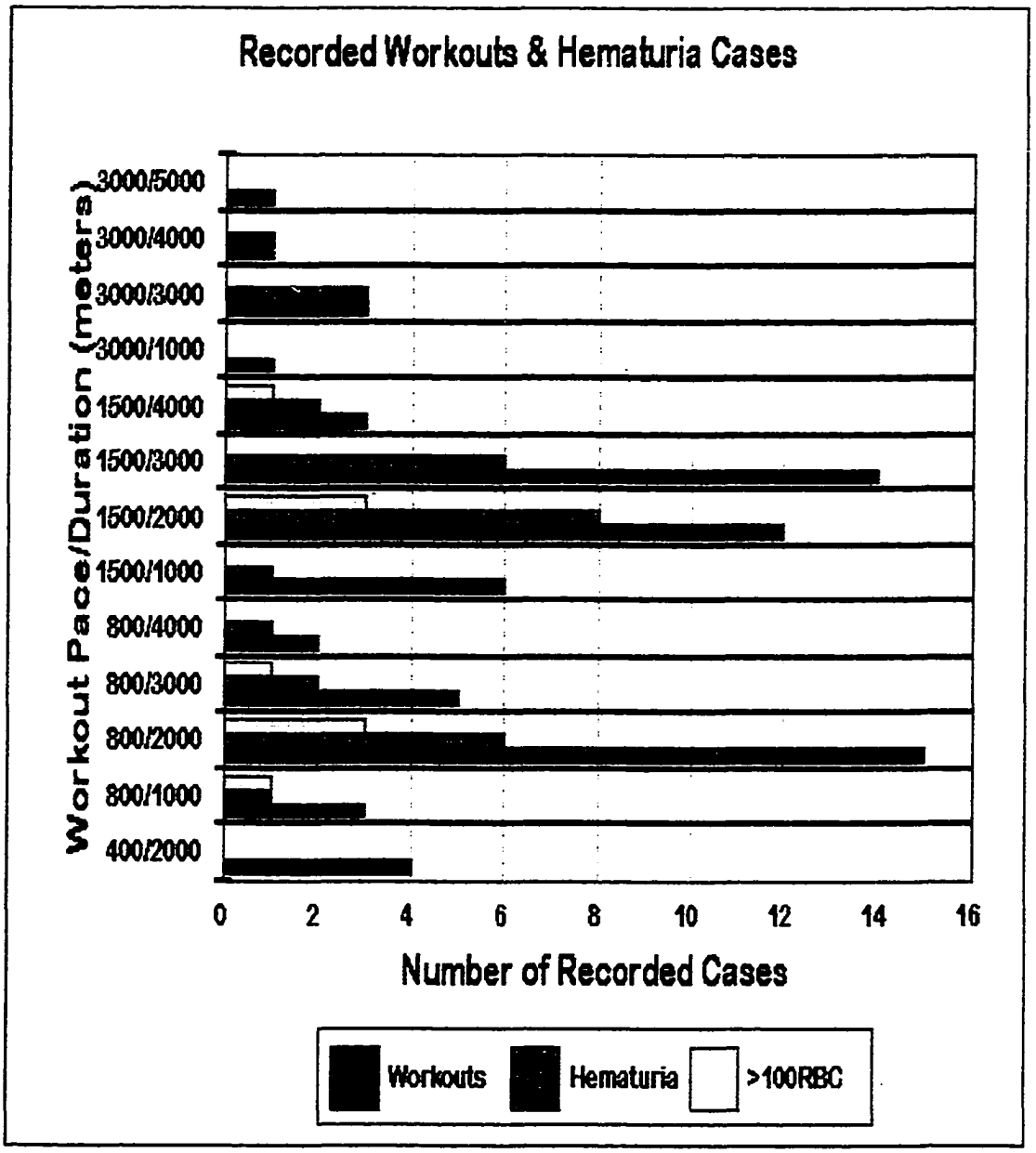
samples, with high hematuria recordings (20-100 RBC per HPF), were often filled with microcytic RBC. These microcytic RBC usually disappeared in follow-up urine samples or were replaced by smaller numbers of more normally sized RBC. To date their has been no study which has reported such extreme losses of microcytic RBC.

Table 3. The percentage of all workouts for each subject with positive urine samples for hematuria.

Subject	Workouts Completed	% Workout >3RBC	% Workout >100RBC
1	9	67	33
2	5	100	80
3	8	88	13
4	7	14	0
5	7	0	0
6	3	67	0
7	8	25	13
8	7	29	0
9	8	22	0
10	7	50	0
Total	**69**	**Average**	**45**	**Average**	**13**

(% rounded up)> 3 RBC per HPF = Hematuria
>100 RBC per HPF = Maximum Hematuria

Figure 4. Reported hematuria cases for completed workouts as classified by pace and distance. Each duration represents a 1000 m range and the number given is the largest for that range.



Cases of hematuria (> 3 RBC per HPF) occurred in ten out of thirteen completed workout classifications, and five workouts produced maximal hematuria (>100 RBC per HPF) (Figure 4). The greatest number of workouts completed by the group was fifteen at the 800 m pace and a duration ranging from 1001-2000 m. This workout produced six cases of hematuria of which three cases had >100 RBC per HPF. The mean measures of exertion for the 800/2000 m workouts were a pBla of 14.8 $\pm$ 4.7 mmol/L, a RPE of 7.5 $\pm$ 1.5 and a work time above 65% VO_2max of 10.0 $\pm$ 8.2 minutes (Table 4). The greatest number of observed hematuria cases were eight of which three cases had >100 RBC per HPF at the subject's 1500 m running pace and at a duration of 1001-2000 m. A total of twelve workouts were completed at this workout classification. The mean exertion levels recorded for the runners following this workout were 11.7 $\pm$ 3.2 mmol/L for pBla , 7.6 $\pm$ 3.2 for RPE and 15.6 $\pm$ 8.3 minutes for time above 65% VO_2max (Table 4). The highest incidence of hematuria occurred at their 3000 m pace with durations of 2001-3000 m. Hematuria was observed following all three of the completed workouts in this grouping where the mean pBla was 11.86 mmol/L $\pm$ 2.1, the mean RPE was 9.0 $\pm$ 1.0 and the mean workout time spent above 65% of VO_2 was 18.9 $\pm$ 4.4 minutes. The majority of running workouts were completed at 800 m and 1500 m pace with durations between 1001-2000 m and 2001-3000 m. Measures of exertion for these groups are shown on Table 4.

This research was unable to give a conclusive answer as to which of the thirteen workout classifications was the most influential in causing hematuria

because there was an uneven number of participants in each workout classification. The results do reveal that hematuria occurred in 77% of all completed workouts and therefore middle distance runners do suffer from hematuria following interval training in the competitive season.

Table 4. Measures of exertion.

Workout Pace /Duration (m)	n	pBla mmol/L	RPE (0.5 - 10)	65% of VO_2 minutes
400/1001-2000	4	12.7 ± 2.0	7.1 ± 0.9	23.2 ± 6.6
800/500-1000	3	11.7 ± 7.5	6.3 ± 2.5	3.5 ± 2.1
800/1001-2000	15	14.8 ± 4.7	7.5 ± 1.5	10.0 ± 8.2
800/2001-3000	5	20.5 ± 9.3	8.6 ± 0.5	21.0 ± 7.9
800/3001-4000	2	7.9 ± 1.6	8.0 ± 0.0	22.1 ± 6.5
1500/500-1000	6	7.3 ± 1.1	5.0 ± 1.1	3.2 ± 0.9
1500/1001-2000	12	11.7 ± 3.2	7.6 ± 3.2	15.6 ± 8.3
1500/2001-3000	14	14.9 ± 3.2	6.8 ± 1.4	16.4 ± 5.4
1500/3001-4000	3	9.6 ± 1.3	8.0 ± 1.0	16.9 ± 2.5
3000/500-1000	1	5.1 ± 0.0	7.0 ± 0.0	11.3 ± 0.0
3000/2001-3000	3	11.9 ± 2.1	9.0 ± 1.0	18.9 ± 4.4
3000/3001-4000	1	12.0 ± 0.0	8.0 ± 0.0	25.5 ± 0.0
3000/4001-5000	1	14.6 ± 0.0	9.0 ± 0.0	26.3 ± 0.0

Number of workouts (n) ,4 minute post blood lactate (pBla), the rating of perceived exertion (RPE) and time worked above 65%$V0_2$max (65% of VO_2). Values shown are mean. ± SD.

Supplementary measures of exertion were; 4 min pBla, RPE, and workout time above 65% of VO_2max. It was anticipated that these measures may help define a specific exercise intensity which induces hematuria. Tables 4 and 5 reveal that the subjects as a whole were working at a high intensity as pBLa and RPE were, in general, quite high. The highest mean pBLa reading of 20.47 ± 9.3 mmol/L was recorded for workouts of 800 m pace and 2001-3000 m in duration. Two cases of hematuria were reported, after completion of this 800/2001-3000 m workout. The highest recorded mean RPE was 9.0 ± 1.0 following a workout of 3000 m pace and 2001-3000 m in duration. All three workouts completed for this intensity exposed the athletes to hematuria. Workout time spent above 65% of individual VO_2 max was 26.3 ± 0.0 minutes for one individual who completed a workout at 3000 m pace and 4001-5000 m in duration. This subject did not suffer from hematuria. The measures of exertion and the mean RBC loss for each individual are exhibited in Table 5.

Table 5. The mean occurrence of hematuria and the measures of exertion for each individual.

Subject	RBC loss	pBla	RPE	65% VO_2
1	35.9 ± 45.5	14.7 ± 5.0	7.9 ± 1.4	10.0 ± 3.6
2	81.4 ± 37.2	12.2 ± 3.1	6.4 ± 1.4	11.8 ± 7.2
3	18.3 ± 31.7	11.5 ± 2.2	8.1 ± 1.5	16.8 ± 5.1
4	1.0 ± 1.6	9.7 ± 2.1	6.0 ± 1.7	27.2 ± 2.9
5	0.4 ± 1.1	14.9 ± 7.0	7.1 ± 1.6	19.1 ± 6.9
6	15.3 ± 17.6	9.5 ± 3.1	8.0 ± 0.8	18.4 ± 7.1
7	16.3 ± 33.1	11.6 ± 3.6	6.4 ± 1.9	7.6 ± 4.3
8	9.3 ± 17.4	14.6 ± 6.1	7.3 ± 1.4	8.8 ± 5.0
9	2.6 ± 5.1	14.6 ± 6.7	7.9 ± 0.8	24.3 ± 5.5
10	6.9 ± 8.6	13.4 ± 3.8	7.8 ± 0.7	17.6 ± 4.5

Values shown are subject means and ± SDs for RBC loss (per HPF), 4 minute post blood lactate (pBla), the rating of perceived exertion (RPE) and time worked above 65% VO_2.

Table 5 reveals that the mean measures of exertion had little effect in predicting the amount of RBC loss for each individual. Each individual responded differently to the interval training workouts throughout the four week collection period. Subject two lost an average of 81 RBC per HPF following every workout he completed. His mean 4min pBLa was 12.2 mmol/L, mean RPE was 6.4 and mean exercise time above 65% of VO_2 max was 11.8 minutes. These values were well within the normal values for the group (Table 7). Subject nine had the highest mean pBLa of 15.66 mmol/L yet his average RBC loss was only

2.3 RBC per HPF. As a group the mean peak blood lactate was reported as negatively correlated to mean running duration, $p<.05$ (Table 8). The highest mean RPE reading of 8.0 was recorded by subject three who produced an average RBC loss of 18.2 per HPF. No significance was found for the group's mean rating of perceived exertion and is thus not reported. The greatest average exercise time above 65% of VO_2 was 28.6 minutes by subject four who had a mean loss of 1.17 RBC per HPF. The group mean time above 65% VO_2 was negatively correlated with the mean red blood cells loss ($p<.05$) and positively correlated to the loss of granular casts ($p<0.1$) (Table 8).

Table 6 displays the urinary findings for the thirteen workout classifications in which the group participated. These results show the change between pre and post workout urine samples. The urine became more acidic and highly concentrated following interval workouts. Proteinuria and granular casts were observed despite the presence of RBC. A conclusive answer to which workout caused the greatest urinary changes may not be established, as unequal numbers of subjects participated in each workout classification.

Table 6. Urinary findings for hematuria, pH, specific gravity, proteinuria and granular casts for each completed workout classification.

400m/1001-2000m	Hematuria (HPFx100)	pH	Specific Gravity	Proteinuria (x100mg/dL)	Granular Casts (LPFx40)
pre	0.0± 0.0	5.6 ± 0.95	1.025 ± 0.0	0.0 ± 0.0	n/a
post	0.0± 0.0	5.3 ± 0.5	1.027 ± 0.003	1.0 ± 0.0	30.0± 17.3
800m/500 -1000m					
pre	0.0 ± 0.0	6.3± 0.3	1.020 ± 0.007	0.0 ± 0.0	n\a
post	33.3 ± 57.7	5.0± 0.0	1.030 ± 0.0	1.0 ± 0.0	13.3± 5.8
800m/1001-2000m					
pre	0.0 ± 0.0	6.1± 0.7	1.024 ± 0.005	0.0 ± 0.0	n/a
post	26.8 ± 44.3	5.2± 0.4	1.029 ± 0.002	0.9 ± 1.15	36.0± 21.2
800m/2001-3000m					
pre	0.0 ± 0.0	6.5± 0.6	1.020 ± 0.008	0.0 ± 0.0	n/a
post	20.8 ± 44.3	5.4 ± 0.5	1.030 ± 0.0	1.4 ± 1.4	33.3± 28.9
800m/3001-4000m					
pre	0.0 ± 0.0	7.0± 0.7	1.022 ± 0.003	0.0 ± 0.0	n/a
post	12.5 ± 17.7	5.0± 0.0	1.030 ± 0.0	0.3 ± 0.0	25.0± 0.0
1500m/500-1000m					
pre	0.0 ± 0.0	6.7± 1.0	1.024 ± 0.008	0.0 ± 0.0	n/a
post	0.8 ± 2.0	5.7± 0.8	1.026 ± 0.006	0.4 ± 0.51	36.7± 23.1
1500m/1001-2000m					
pre	0.0 ± 0.0	6.0± 0.9	1.024± 0.007	0.0 ± 0.0	n/a
post	29.0 ± 43.7	5.2± 0.4	1.028± 0.002	1.3 ± 1.08	34.0± 21.0
1500m/2001-3000m					
pre	0.0 ± 0.0	6.4 ± 0.9	1.020± 0.006	0.0 ± 0.0	n/a
post	9.8 ± 26.3	5.4 ± 0.6	1.028± 0.003	1.3 ± 1.08	31.9± 20.7
1500m/3001-4000m					
pre	0.0 ± 0.0	6.8± 0.3	1.016± 0.015	0.0 ± 0.0	n/a
post	35.3 ± 56.1	5.0± 0.0	1.028± 0.003	0.5 ± 0.40	29.0± 4.3
3000m/500-1000m					
pre	0.0 ± 0.0	5.0± 0.0	1.015± 0.0	0.0 ± 0.0	n/a
post	0.0 ± 0.0	6.0± 0.0	1.030± 0.0	0.0 ± 0.0	n/a
3000m/2001-3000m					
pre	0.0 ± 0.0	6.3± 0.4	1.022± 0.59	0.0 ± 0.0	n/a
post	9.7 ± 0.0	6.3± 1.0	1.028± 0.003	1.7 ± 1.15	13.7± 14.8
3000m/3001-4000m					
pre	0.0 ± 0.0	5.0 ± 0.0	1.025± 0.0	0.0 ± 0.0	n/a
post	40.0 ± 0.0	5.0 ± 0.0	1.030± 0.0	3.0 ± 0.0	50.0± 0.0
3000m/4001-5000m					
pre	0.0 ± 0.0	n/a	n/a	n/a	n/a
post	0.0 ± 0.0	6.5± 0.0	1.025± 0.0	1.0 ± 0.0	20.0± 0.0

Results were determined using reagent strip analysis for pre-test samples and microscopic analysis for postive post-test samples. Values represent Mean ± SD.

Table 7. Group findings.

Variable	Weighted Mean	± SD	Range
Running pace (m)	1358.77	572.8	628.6 - 2500
Duration (m)	2044.70	555.7	600 - 4500
pBla (mmol/l)	12.8	2.2	9.5 - 15.7
RPE	7.3	0.8	6 - 8.06
65%VO_2(min)	16.1	6.5	7.6 - 27.21
Casts (LPF)	31.5	15.5	1 - 50
Proteinuria (g/l)	1.25	0.9	0 - 3
RBC (HPF)	20.33	24.8	0.43 - 81.4

Running pace, duration , 4 minute post blood lactate (pBLa), rating of perceived exertion (RPE), workout time above 65% of VO_2 max (65%VO_2), post urinary granular casts (Casts), post urinary proteinuria and post urinary red blood cells (RBC). N=10.

Table 8. Correlations for the variables

***p<0.1, **p<.05, ***p<.001**

	RBC	Casts	Pro	pBLa	VO_2	pH	SG	PACE	Dist
RBC	1.0								
Casts	.3398	1.0							
Pro	-.1171	.1892	1.0						
pBla	-.1945	.4640	-.4904	1.0					
VO_2	** -.7205	* .5635	-.1125	-.0354	1.0				
pH	.2943	-.0748	-.3144	-.0097	-.2536	1.0			
SG	.1245	.2215	.1845	.1512	.0335	*** -.8854	1.0		
PACE	-.5055	-.2528	* .5853	-.3811	.3709	.0212	.0053	1.0	
Dist	-.0857	-.2943	** .7487	** -.7585	-.0770	.0421	-.1401	* .6179	1.0

Red blood cells (RBC), granular casts (Casts), Protein (Pro), 4 min. peak blood lactate (pBla), workout time above 65% of VO_2 max (VO_2), post urine pH, post urine specific gravity (SG), workout running pace (PACE) and duration (Dist).

Figure 5. Mean occurrence RBC, protein and granular cast loss per individual.

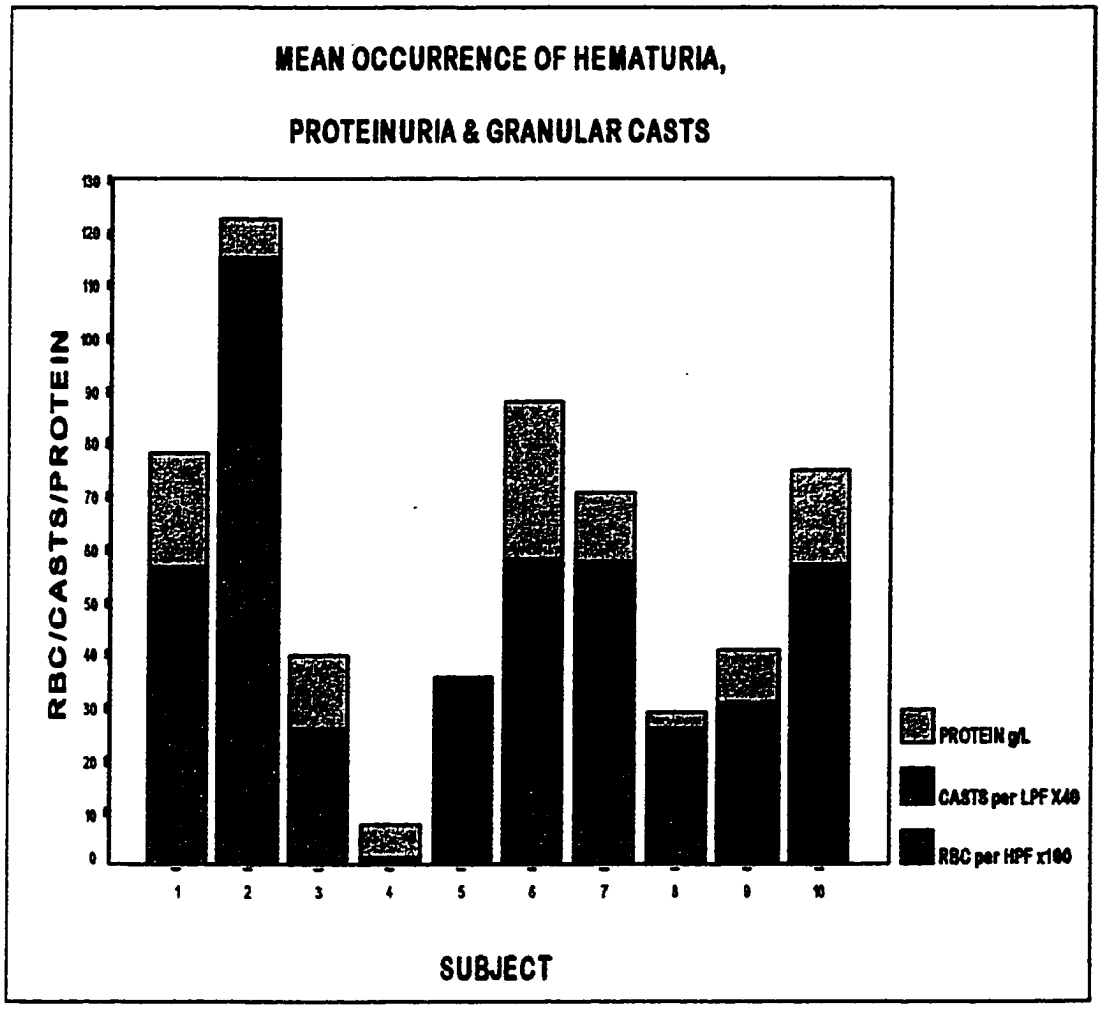


Figure 5 reveals that protein and granular casts are excreted in the urine along with RBC following strenuous activity. Eight subjects exhibited protein and granular cast loss in concert with RBC loss. Subjects four and five, had negligible RBC loss but protein and granular cast loss were observed. Protein loss was significantly related to running pace at $p<.05$ and running distance at $p<0.1$ levels (Table 8).

Individual subject data may be visually inspected to detect patterns that may not emerge from grouped data. Kazdin (1982) stated that data means, level of change, trends, and latency of change between onset and termination may all be used to describe the magnitude of change. Figure 6 illustrates the mean supplementary measures of exertion and the urinary findings for subject seven. Subject seven was chosen to illustrate the study group as he completed most of the workouts and provided results that closely represent the average scores of the group. Complete plots for subjects 1 through 10 may be found in Appendix A.

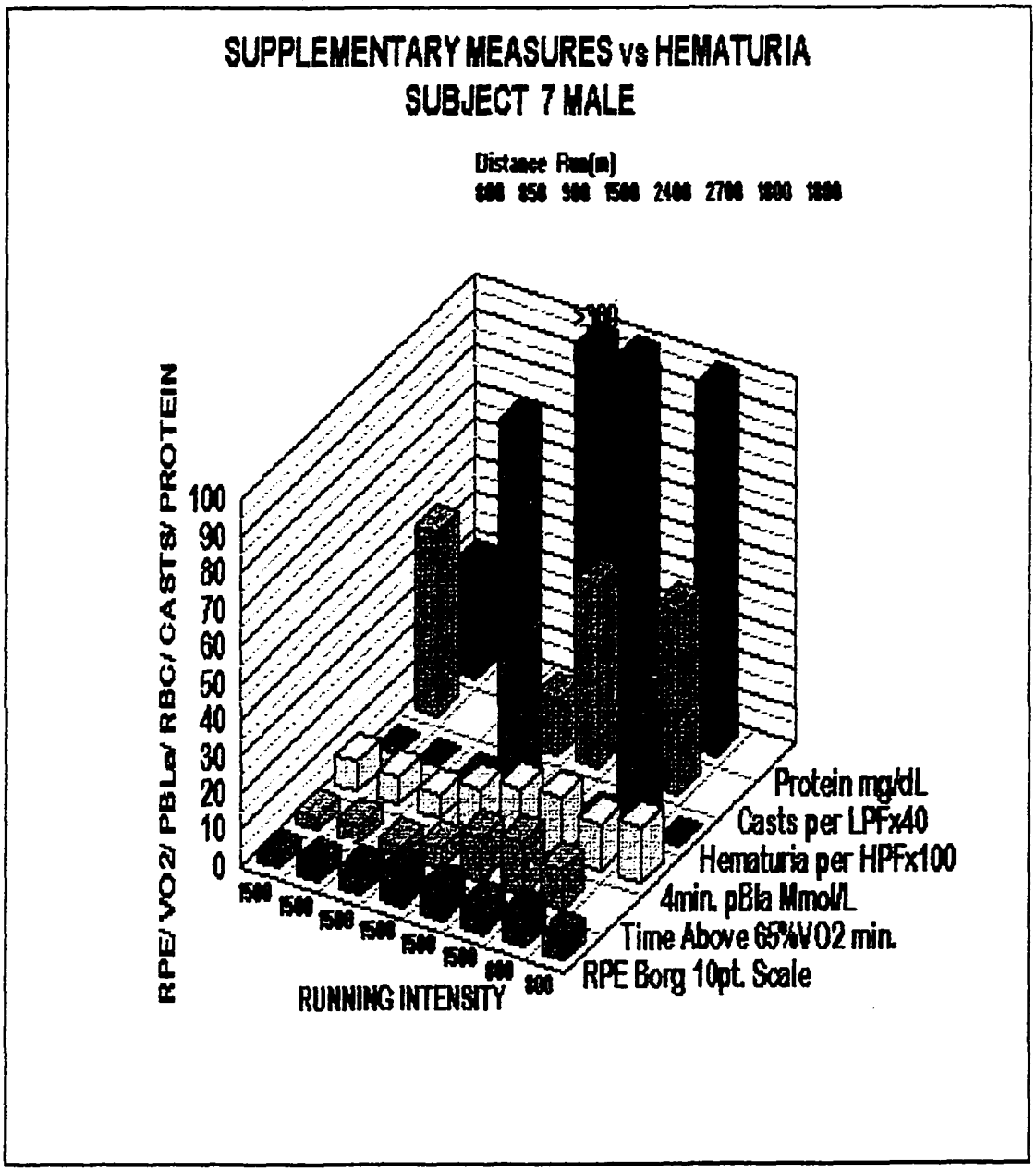
The individual bar graphs represent the changes exhibited between the different workouts in which the subject completed. The x-axis represents the running paces for each workout and the duration of each workout may be observed at the top of each bar graph. Workouts increase in intensity from left to right. The supplementary measures of exertion generally rose with increasing running intensity.

Subject seven's rating of perceived exertion rose from 3 to 9 on the Borg 10pt. scale (Borg, 1982), but dropped from 8 to 6 following workouts of 800 m

pace. The amount of workout time spent by subject seven working above 65% of his VO_2 max. increased from 3.5 minutes to 14.5 minutes. Similar results were seen for 4min. peak blood lactate. The lowest recorded peak blood lactate was 8.35 mmol/L following a workout at 1500 m pace and 800 m in duration and increased to 15.23 mmol/L following a workout of 800 m pace and 1800 m in duration. Post workout urinary findings did not display similar linear relationships with running intensity.

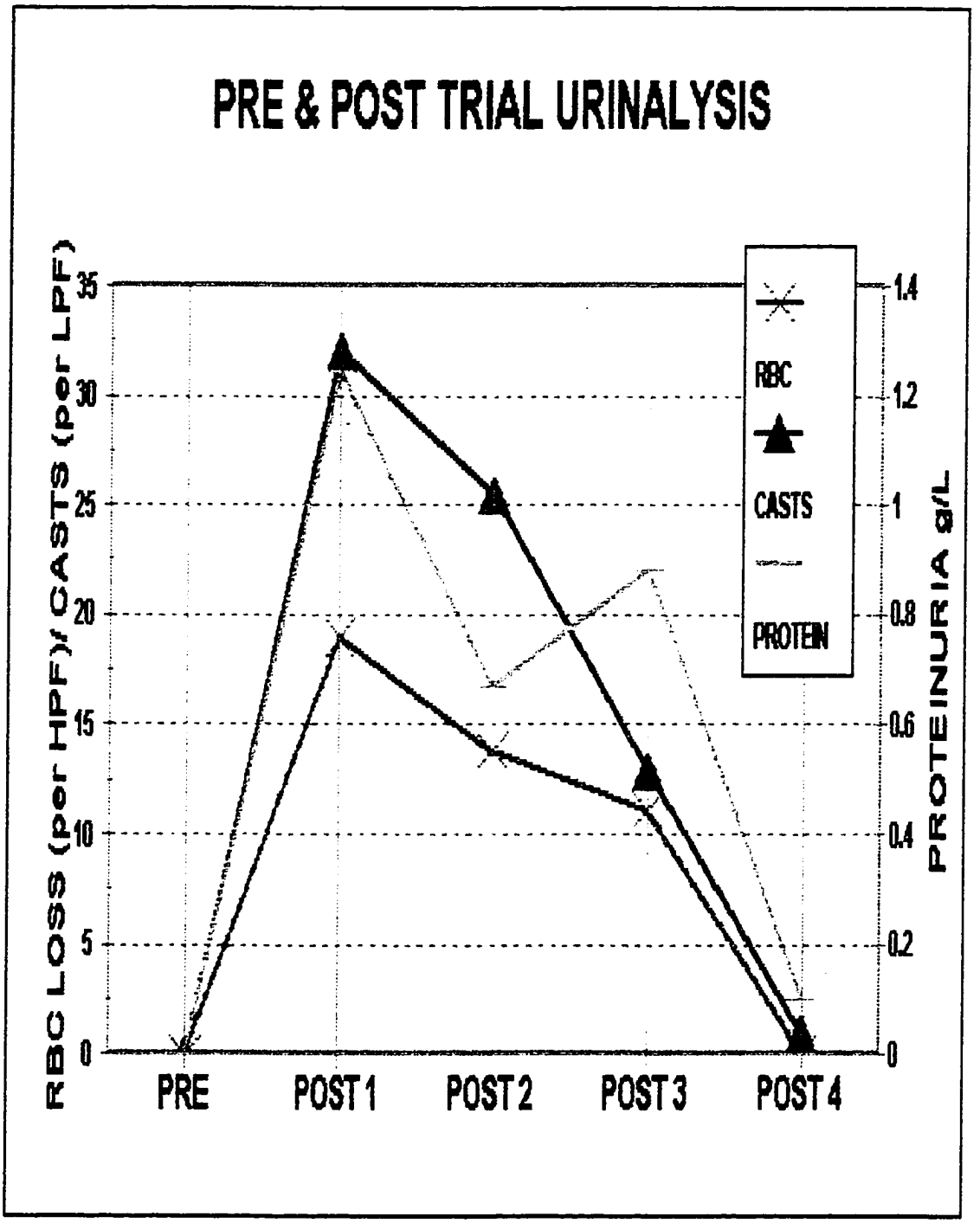
Figure 6. Subject 7. Individual mean supplementary measures of exertion.

*** >300 represents a urinary protein concentration of 300mg/dL or 3g/L. This value is the highest reading given from reagent strip analysis (Ames. Multistix 10 SG.).**



Subject seven experienced hematuria following two of his eight recorded workouts. Hematuria of >100 RBC per HPF was exhibited following a workout of 1500 m pace and 1500 m in duration. The second incidence of hematuria was reported following a workout of 800 m pace and 1800 m duration but a second trial at the same intensity did not elicit hematuria. Granular casts and protein were recorded following four workouts regardless of RBC loss, yet maximal scores of 50 casts per LPF and >300 mg/dL of protein were observed with urine samples containing RBC.

Figure 7. Mean values of hematuria, proteinuria and granular casts for the pre-workout urine samplings and for the post-workout samplings in which hematuria became evident.



Pre-workout urinalysis revealed that the study group did not exhibit hematuria, proteinuria, nor granular casts prior to their interval track running workouts. The group's first post-workout urine samples exhibited hematuria, proteinuria, and granular cast. The average RBC, protein, and granular cast loss for the first post workout urine sample was 18.96 RBC per HPF, 1.24g/L and 32.01 casts per LPF respectively. Follow-up urine samples, collected within a two hour period, demonstrated that these abnormal conditions were resolved to levels similar to those taken prior to the workout (Figure 7).

Figure 8. Mean urinary pH and specific gravity measures of positive hematuria samples for the study group.

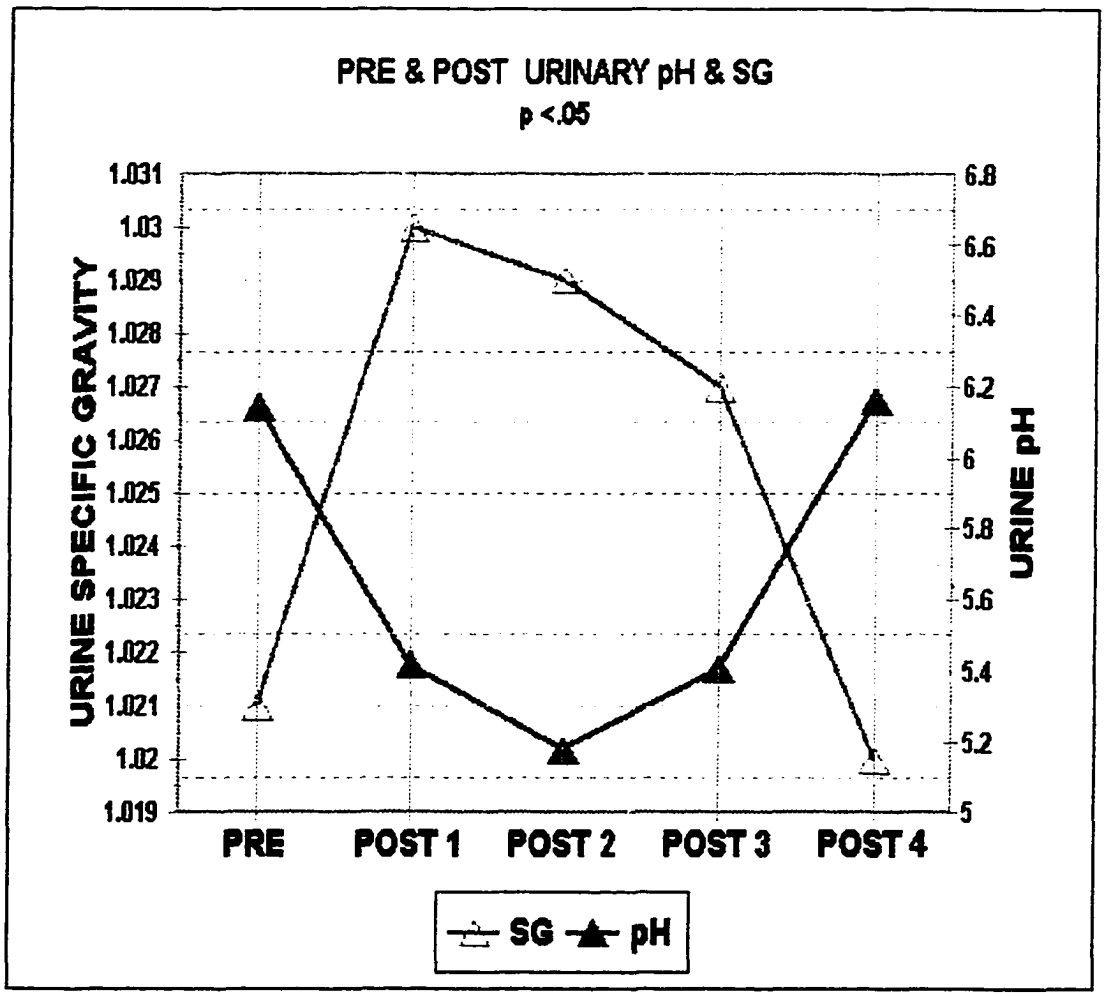


Figure 8 shows the change in urinary pH and specific gravity between pre and post-workout samples. Urinary pH and specific gravity both peaked during the second post test sample and rapidly returned to normal between the third and fourth samples. Urinary pH levels returned to more basic levels than those reported in the pre-workout urine samples, whereas the specific gravity of the urine returned to pre-workout levels. These variables presented a strong correlation of $p<0.001$.

CHAPTER 5

DISCUSSION

Nine of the ten subjects showed a significant RBC loss (>3 per HPF) in at least one workout during this study. This study also found a 66% incidence of hematuria following twelve workouts at 1500 m pace and 1001-2000 m in duration. McInnis and Newhouse (1993) reported a 100% incidence of hematuria following a more strenous 3 x 400 m all-out sprint protocol. Alyea and Parish (1958) found that 80% of the track runners in their study group experienced hematuria following events between 440 yrds to 1500 m, while Fassett, Owen, Fairley, Birch and Fairley (1982) reported a 69% incidence of hematuria in athletes running longer distances of nine and fourteen kilometres. Both studies found that exercise can cause an appreciable rise in RBC loss.

As shown by previous studies (Alyea and Parish, 1958; Cianflocco, 1992) hematuria appears to be caused by duration and intensity of exercise rather than direct renal trauma. Unlike most research in this area, the present study focused on the relationship between exercise intensity and duration on hematuria. Cianflocco (1992) claimed that the longer and more strenuous the work, the more common and prominent the hematuria. Even though the present study had unequal numbers of participants in each of the thirteen workout classifications,

the greatest incidence of hematuria was observed following workouts of 800 m and 1500 m paces and durations between 1000 m to 4000 m as revealed from table 3. Support for this finding can be found in Poortmans (1984), Castenfors (1977), and Abarbanel et al. (1990) who reported that workouts of sufficient intensity and duration were likely to cause hematuria due to hypoxic damage at the kidney. The workout duration in this study was not as long as other times reported in other studies (Helzer-Julin et al., 1988; Kachadorian and Johnson,1970) thus the cause of hematuria may have been more intensity related.

Microscopic analysis revealed that at no time was hemolysed red blood cells observed in the urine sediment, eliminating the possibility of a haptoglobin deficit due to intra-vascular and/or foot strike hemolysis (Dufaux et al. 1981; Eichner, 1990; Falsetti et al., 1983) and the effect of a hemolysing factor (Shiraki et al., 1984; Lindemann et al., 1978). Poortmans (1984) claimed that reduced levels of haptoglobin allowed free hemoglobin to pass through the glomerulus while under normal conditions the haptoglobin-hemoglobin complexes are too large to pass through the glomerular wall. Castenfors (1977) and Poortmans (1984) also suggested that exercise stress induced a greater glomerular filtration fraction allowing the escape of proteins and whole red blood cells. This study found both protein and RBC in the group's post-workout urine samples (Figure 7) and that a significant relationship ($p<.05$) existed between proteinuria and running pace. This finding was consistent with that of Helzer-Julin et al. (1988) who reported a significant relationship ($p<.05$) between running intensity and proteinuria.

Urine samples with greater than 100 RBC per HPF revealed RBC which were microcytic, making them difficult to see under the microscope. In the concentrated, acidic urine produced by the study group (Figure 8), the RBC were very small and crenated making them easily mistaken for yeast cells or oil droplets (Strasinger, 1989). Acetic acid (ZAP-Globulin) was added to these samples to verify that RBC were being observed. The lysing action of the acetic acid left the urine sediment free of RBC thus permitting a positive identification.

It may be speculated that the dehydration experienced by the athlete during the workout led to the increased concentration (specific gravity) and acidic pH of the urine. This hypotonic environment may cause the RBC that passed through the glomerular membrane to shrink and be excreted as microcytic RBC. These findings are supported by Helzer-Julin et al. (1988) who reported that exercise intensity and mild dehydration have been significant factors in causing hematuria. As the athlete rehydrated themselves following the workout these microcytic red blood cells returned to normal size in follow up samples but their numbers were greatly reduced (Figure 7).

Track athletes and coaches should be made aware that workout combinations of 800 and 1500 m pace with 1000-4000 m in duration could readily produce hematuria. Fortunately these abnormal urine conditions were transient and the urine sediment returned to normal by the fourth post-workout sampling (Figure 7). Exercise induced hematuria is not a chronic problem since it resolves itself within twenty-four hours (Helzer-Julin et al.,1988; Hoover and Cromie,

1981; Kachadorian and Johnson, 1970) or less as observed in this study in 1-2 hours.

Supplementary measures of exertion, 4min. peak blood lactate, RPE, and work time above 65% of VO_2max were compiled from the individual's workouts. This data was used to determine if there was a possible link between the level of exertion and the incidence of hematuria.

Blood Lactate

Resting blood lactate samples were taken to ensure that other forms of exercise or illness did not contribute to the outcome of the post workout urine samples. The post blood lactate was used to determine if a relationship existed between the amount of accumulated blood lactate and the amount of hematuria. It has been suggested by Javitt and Miller (1952) that the elevated concentration of lactic acid may increase the permeability of the glomerular wall.

The mean resting blood lactate sample taken prior to starting one of the thirteen completed workout groups was 2.5 mmol /L. Most subjects had higher than expected resting blood lactates which may have been due to inadequate recovery from the previous day's workout (Appendix B). The mean 4min. post blood lactate for all thirteen of the completed workout classifications was 11.9 mmol/L. Oukuwa et al. (1984) recorded average 4min. peak blood lactates values for trained distance runners of 14.97 mmol/L after a 400 m race and 12 mmol/L after a 3000 m race. The highest average post blood lactates were observed after

workouts at 800 m pace and of a duration between 2001-3000 m (Table 4). Using individual visual inspection, this study could not show any relationship between 4min. peak blood lactate and the incidence of hematuria even though previous studies implicated high blood lactate to proteinuria (Poortmans et al., 1981). A significant relationship ($p<0.05$) between peak blood lactate and running intensity was shown (Table 8). The results collected from subjects 1 through 10 (Appendix A) indicated that the levels of peak blood lactate were not consistent with the incidence of hematuria. This study does not support the use of blood lactate sampling as an absolute method for predicting exertion levels which promote hematuria.

Rating of Perceived Exertion

The rating of perceived exertion (Borg, 1982) was used to determine if a relationship existed between the RPE and hematuria. RPE was used as a subjective measure of the athletes individual level of exertion for each workout. The RPE scale has been shown to have a significant relationship with blood pH (Robertson, 1985) and therefore the RPE may indicate the exercise exertion level that would elicit hematuria.

This study showed no intra-individual patterns between the RPE and amount of hematuria in the first post workout urine sample. Some subjects suffered hematuria following every workout while others never experienced hematuria. This variation may have been due to the subjective nature of the RPE scale. The

results in this study do not support the use of RPE in predicting hematuria in track runners.

Work time above 65% of VO_2max

The amount of time spent by the subject above 65% of VO_2max was also used to determine if a relationship existed between it and hematuria. It has been suggested that an exercise intensity of 65% of VO_2max would significantly reduce renal blood flow to the kidney (Poortmans, 1984). To compensate for the reduced renal blood flow the glomerular filtration fraction would increase allowing the movement of red blood cells and protein through the glomerular membrane.

The mean VO_2max of the runners is this study was 57.5 ml/kg/min which was slightly higher than the mean VO_2max of Newhouse and McInnis's (1993) group which had a mean VO_2max of 53.0 ml/kg/min. The average amount of time spent above 65% of VO_2max for this group ranged from 3.2 minutes to 26.25 minutes (Table 4).This study was unable to show if time spent working above 65% of an individuals VO_2max was a valid predictor of hematuria.

Urinary pH, specific gravity, the presence of granular casts, and the incidence of proteinuria were studied in the event that they were related to the incidence of hematuria. These variables have all been found to be related to the amount of stress endured by the kidneys during exercise (Strasinger, 1989; Helzer-Julin et al. 1988, Dancaster and Whereat, 1977).

Urine pH

The pH values ranged from 5.0 to 8.0 in the pre workout samples which were within the normal range of 4.5 to 8.0 (Harold et al., 1991). Urine samples which tested positively for RBC loss had average post workout urinary pH ranging from 5.0 to 7.5 on the first sample, 5.0 to 8.5 on the second sample, 5.0 to 5.5 on the third sample, and 6.0 to 7.0 on the fourth sample (Figure 8). Similar observations were made by Fassett et al. (1982) who reported pre and post urine pH readings of 6.2 ± 0.4 and 5.9 ± 0.5 respectively. This may be explained by the subjects becoming more hydrated as they kept drinking more liquids in order to provide urine specimens. There was no relationship between urinary pH and hematuria in this study making urinary pH an ineffective determinant of hematuria.

Specific Gravity

Higher specific gravity of the urine represents increased urine concentration which can be a result of dehydration. The specific gravity is influenced by both the number and size of the particles in the urine, with larger urea molecules having the greatest effect on the reading, rather than smaller particles such as sodium, blood, and protein. In order to distinguish between the effects of urea and the smaller particles on specific gravity, tests of osmolarity would need to be conducted. Pre-workout urine samples had mean specific gravity values ranging

from 1.015 to 1.025 (Table 6). This finding was similar to Helzer-Julin et al (1988) who reported pre test urine samples with specific gravity's between 1.009 to 1.030 which is within a normal range (Strasinger, 1989). Mean specific gravity rose following workouts and returned to baseline levels in follow-up samples (Figure 7). As the urine specific gravity decreased, the RBC returned to normal size (euhydrated). It may be speculated from this study that these runners were not adequately hydrated before and during, their workouts. Goldszer and Seigal (1991) suggested that those with exercise induced hematuria should avoid dehydration by drinking plenty of fluids before exercise. This could be a general recommendation, as athletes should be encouraged to properly hydrate before, during, and after exercise.

Proteinuria

Protein loss may occur in concert with RBC loss (Strasinger, 1985). Marked proteinuria and/or RBC casts may indicate glomerular disease (Eichner, 1990). Normal values for protein concentration are usually in the 10-20 mg/dL range and physically active individuals may have higher than normal proteinuria levels at rest (Helzer-Julin et al., 1988). Abnormal levels of proteinuria in the pre-workout urine samples were not observed in this study but post-workout samples exhibited proteinuria of concentrations of 0 to 300mg/dL. In the present study, 90% of the subjects suffered proteinuria at least once as compared to the reported 70% by Dancaster and Whereat (1971). Dancaster and Whereat (1971) discovered that

increased proteinuria is related to increased hematuria. Similar results were observed in this present study (Figure 5). The glomerulus seems to be the doorway for RBC to enter the nephrons due to the effect of intense exercise on increased glomerular permeability and a saturation of tubular reabsorption as proposed by Poortmans (1977). Thus, the RBC do not necessarily have to be dysmorphic, as indicated by Thompson (1989), in order to pass through the glomerular wall.

Granular Casts

Granular casts were often observed in urine samples containing RBC. Strasinger (1989) noted that the appearance of coarse and/or fine granular casts in the urinary sediment is generally considered to represent disintegrated cellular casts remaining in the tubules as a result of stasis. Their presence can be increased by strenuous exercise (Strasinger, 1989). Figure 5 shows that like protein, the presence of granular casts in the urine can occur with the onset of hematuria. The increased numbers of granular casts in the urine indicates tubular stasis rather than reabsorption. Tubular urine stasis would prevent the reabsorption of red blood cells and therefore contribute to their loss (Poortmans, 1982).

Sex Differences

Sex differences have been reported by Elliot et al. (1991) who state that rarely has hematuria been found in women. It has been reported that hematuria occurs more often in men but now more and more women exhibit hematuria as they become more involved in sport (Hoover and Cromie,1981). Based on visual inspection no differences were observed between genders in this study.

CHAPTER 6

CONCLUSIONS & RECOMENDATIONS

Summary

The procedures of this experiment revealed that hematuria does occur in middle distance track runners during their regular competitive season interval workouts. Single case visual inspection revealed RBC losses of between 4 to >100 per HPF(x100). Proteinuria and granular cast loss were also observed in the urine when hematuria was present. Determining workouts which specifically induce hematuria was difficult as most of the subjects trained at paces of 800 to 1500 m and durations of 2000-4000 m. This study did however show hematuria in ten of the thirteen completed workout classifications (Figure 4). The supplementary measures of exertion were unable to verify hematuria due to the individual differences reported between subjects.

In summary, a strong relationship does exist between hematuria and exercise intensity. This study observed much greater losses of whole red blood cells than any other study reported in the literature, which in itself is significant. It was hypothesized that whole RBC were lost due to the increased renal filtration fraction and glomerular filtration rate of the glomerulus in response to the shunting of blood away from the renal artery to working muscles. Evidence for

this relationship can be rationalized from the microcytic whole red blood cells observed following interval workouts. In this author's opinion, changes to glomerular permeability due to the increased GFF and GFR may be the primary mechanism responsible for hematuria in middle distance track runners. It is hypothesized that increased running intensity will increase glomerular permiability facilitating the passage of RBC and protein through the glomerular membrane. The intensity relationship observed in this present study is consistent with the findings presented in the literature as hematuria was observed in our study group following track running, interval workouts.

Conclusion

The primary hypothesis of this study was accurate, middle distance runners do suffer from hematuria following interval workouts. This study observed an incidence of hematuria following interval workouts of 800 and 1500 m pace with cumulative durations being greater than 1000 m and less than 4000 m, but as there were an uneven number of participants in each workout classification a conclusive answer to which workout would most influence hematuria could not be confirmed. All RBC found in the subjects' urine following the interval, running workouts were intact yet microcytic. The microcytic size of the RBC would suggest a glomerular origin. It is this author's opinion that the hypotonic environment within the nephron and collecting tubules caused the RBC to shrink and be excreted as microcytic RBC. An additional finding of interest was the loss

of >100 RBC per HPF observed in 33% of the study group. The possibility exists that these individuals who experience repeated maximal RBC loss may be susceptible to iron deficiency. There was no observable relationship between the supplementary measures of exertion and hematuria as each subject's results were independent of their level of exertion. The track athlete and coach should be made aware of this condition and possibly screening procedures may need to be implemented since some athletes may experience relatively large losses of RBC and thus increase their susceptibility to iron deficiency.

Recomendations For Further Research

It is suggested that further research in this area should include more control over the number of participants for each type of workout examined. All urine samples should undergo microscopic examination as reagent strips are not reliable indicators of microcytic RBC loss. Quantitative analysis of RBC loss and serum ferritin levels over a full macro cycle of the athlete's training may give a more accurate picture of a potential relationship between hematuria and iron deficiency.

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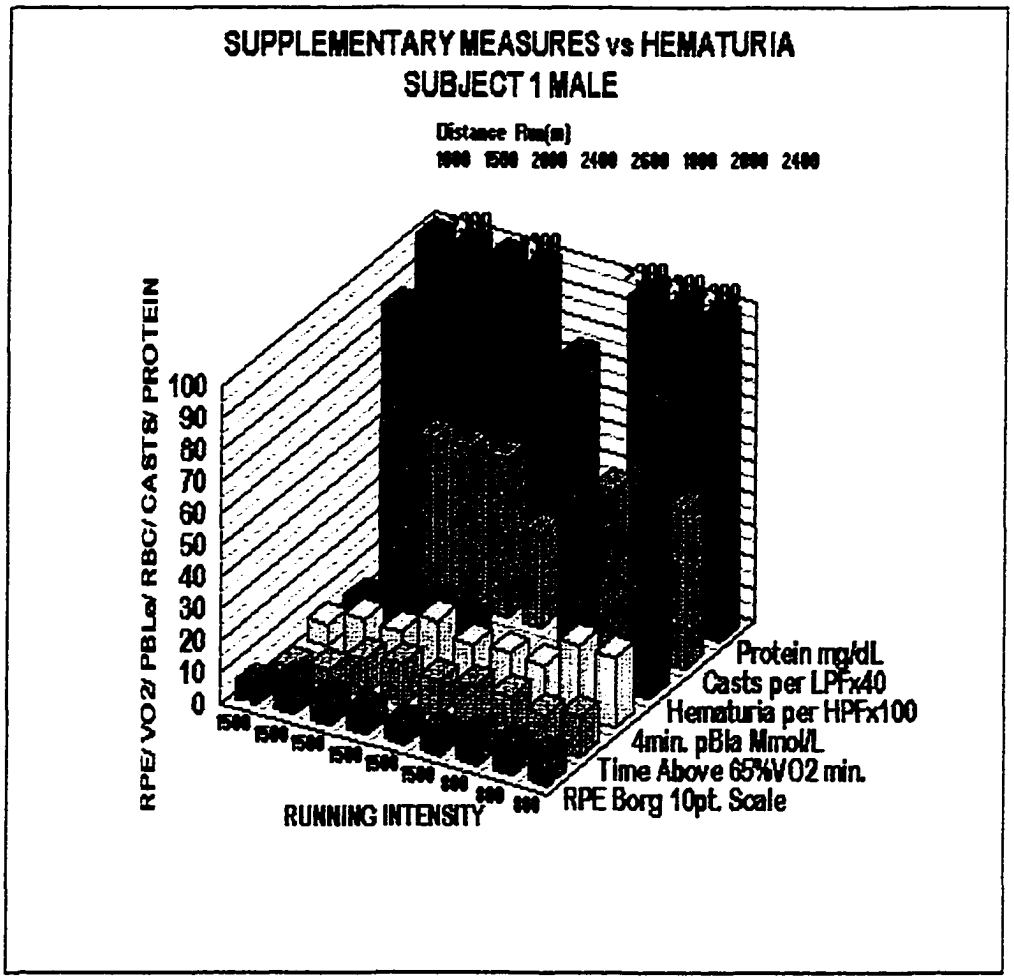
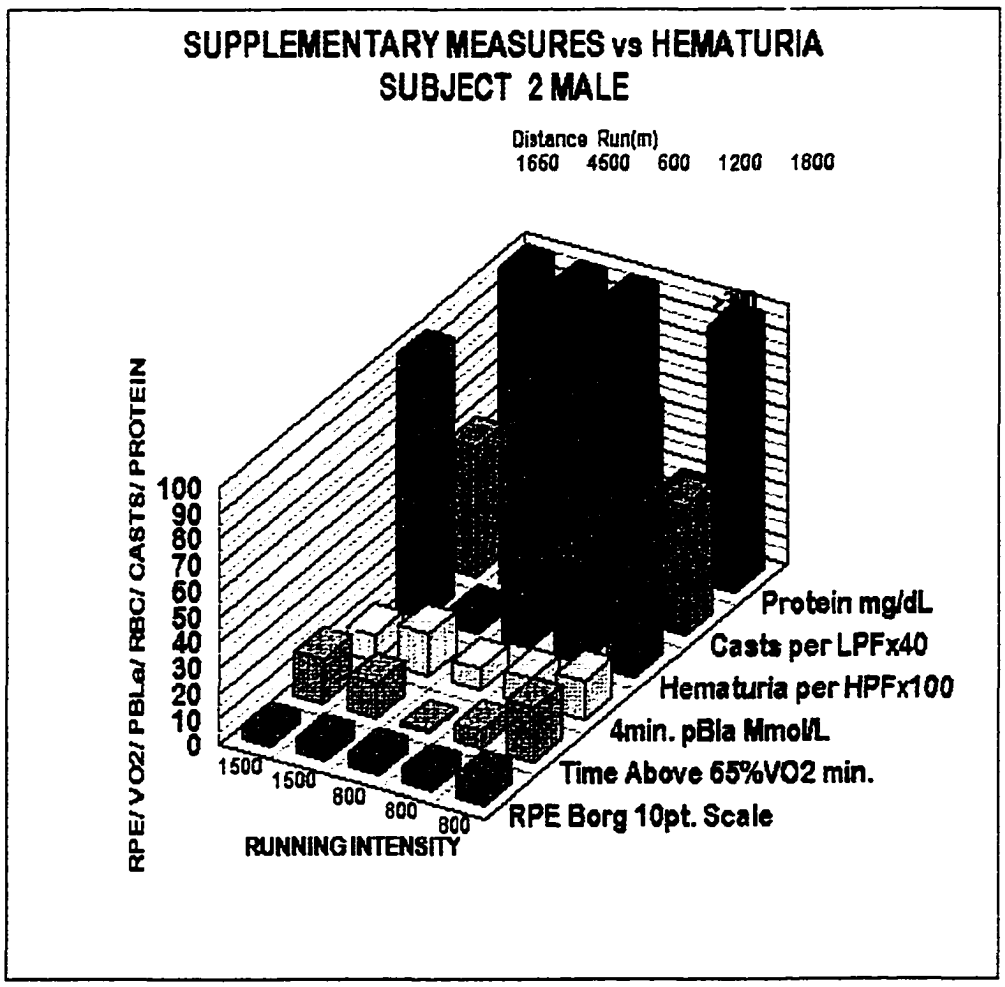
APPENDICES

APPENDIX A. Subjects 1.

Supplementary measures of exertion and urinary findings.
* **>300** represents a urinary protein concentration of 300mg/dL or 3g/L. This value is the highest reading given from reagent strip analysis (Ames.Multistix 10SG).



APPENDIX A. Subject 2



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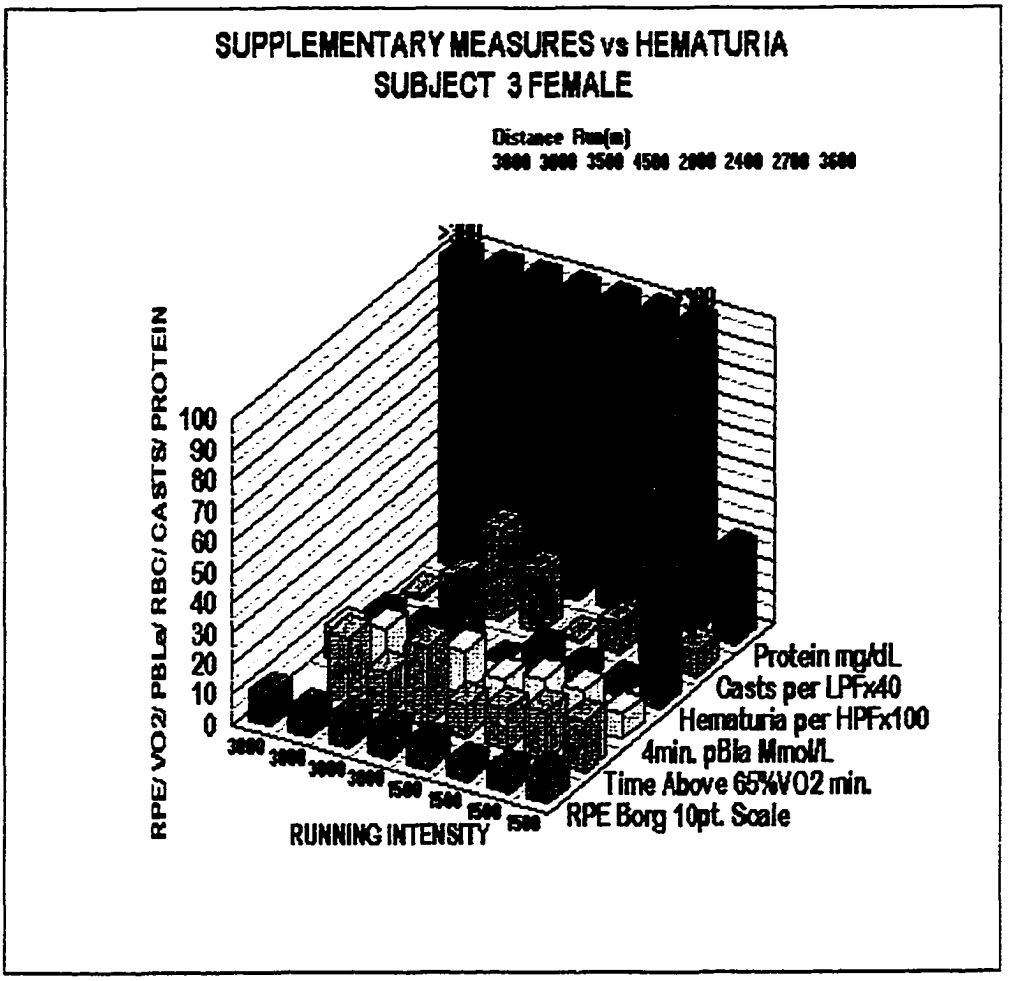

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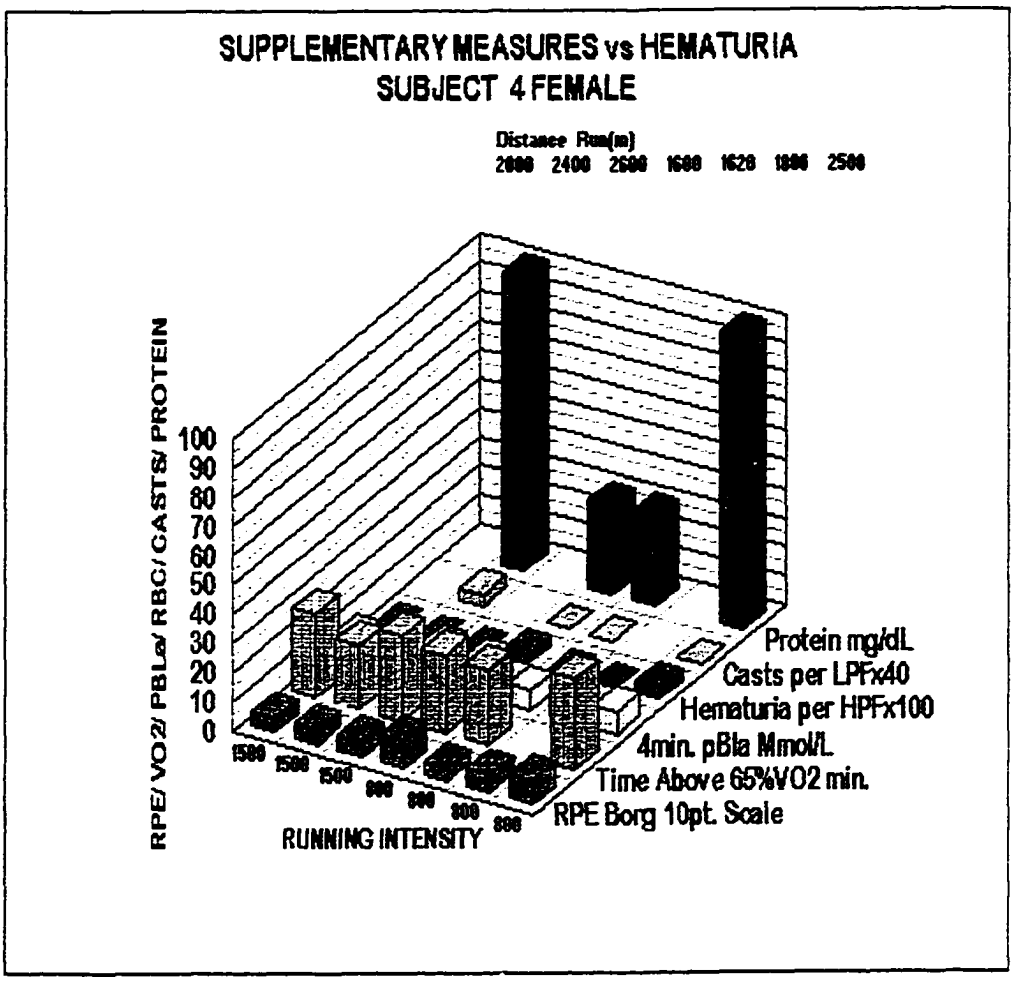

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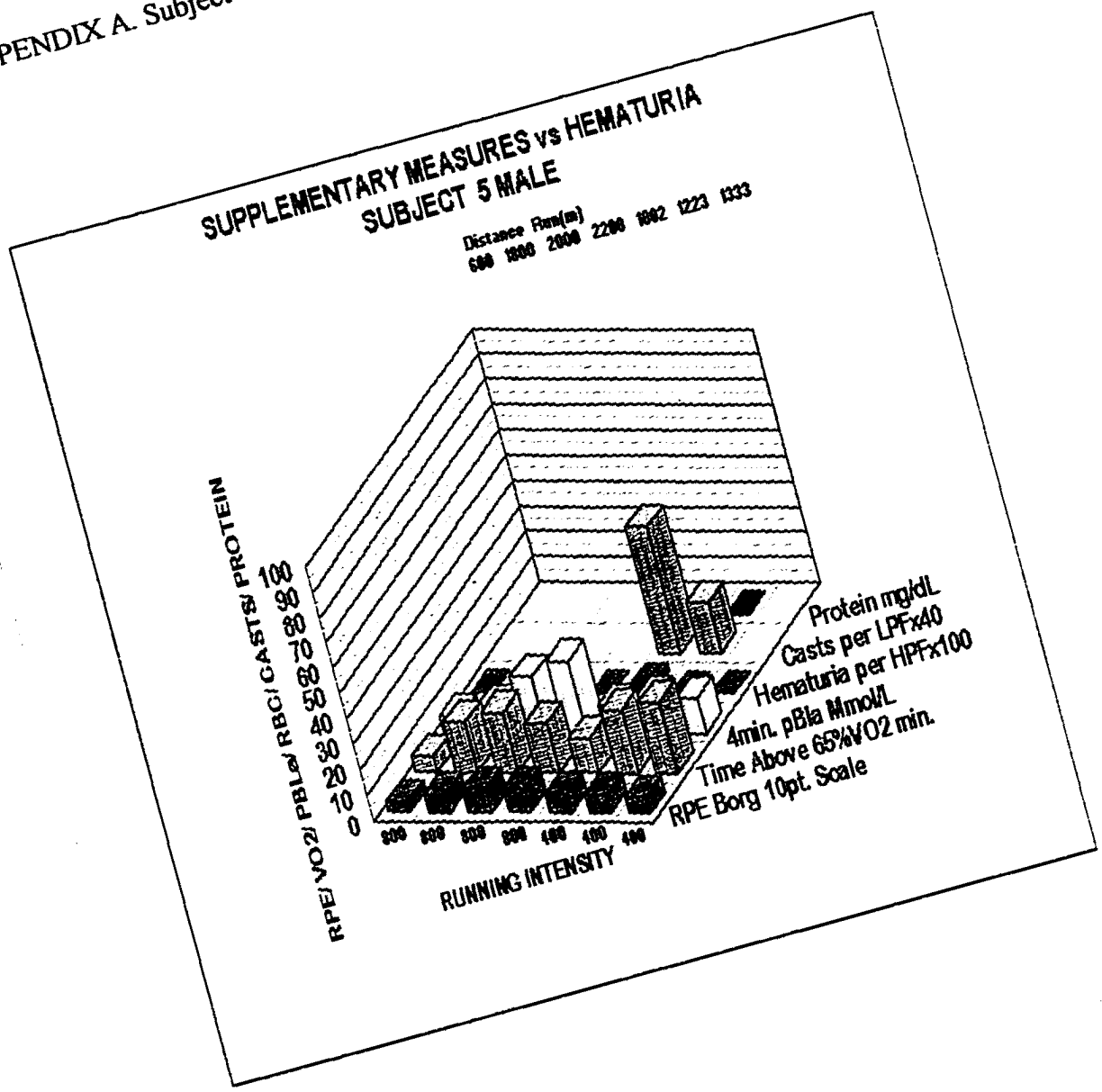

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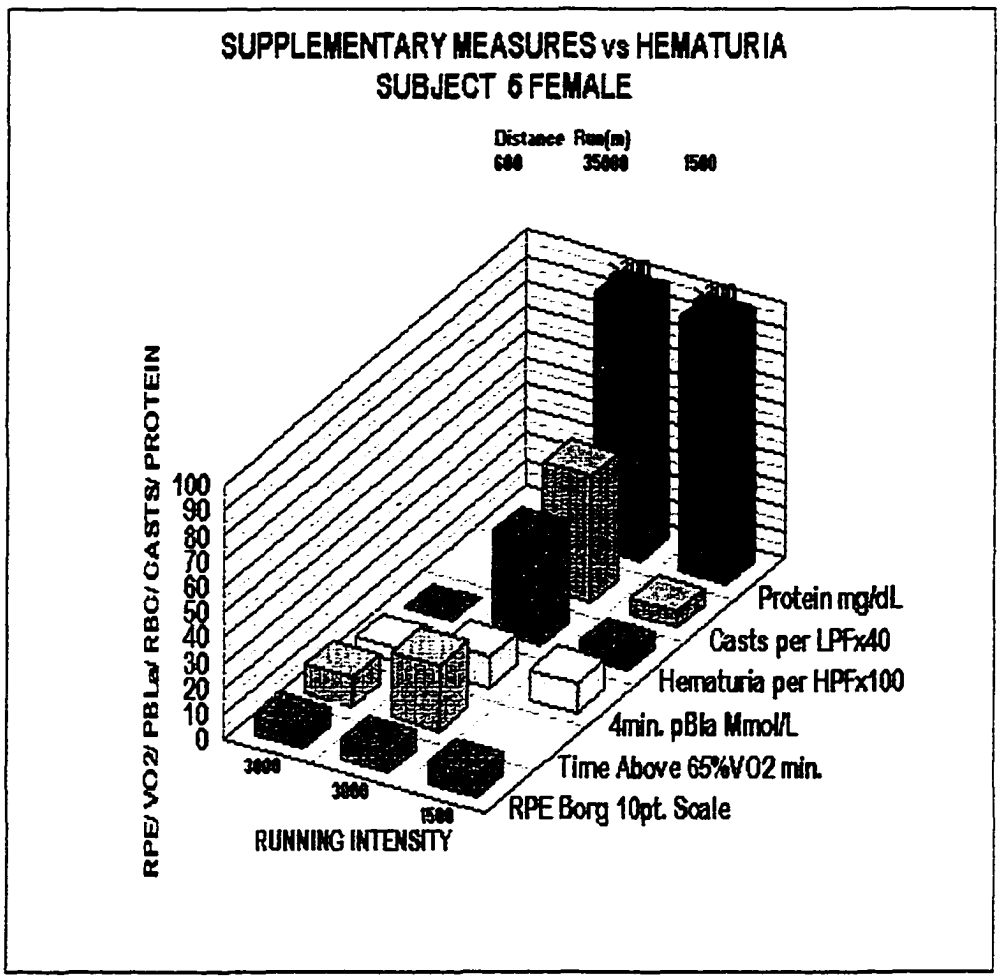

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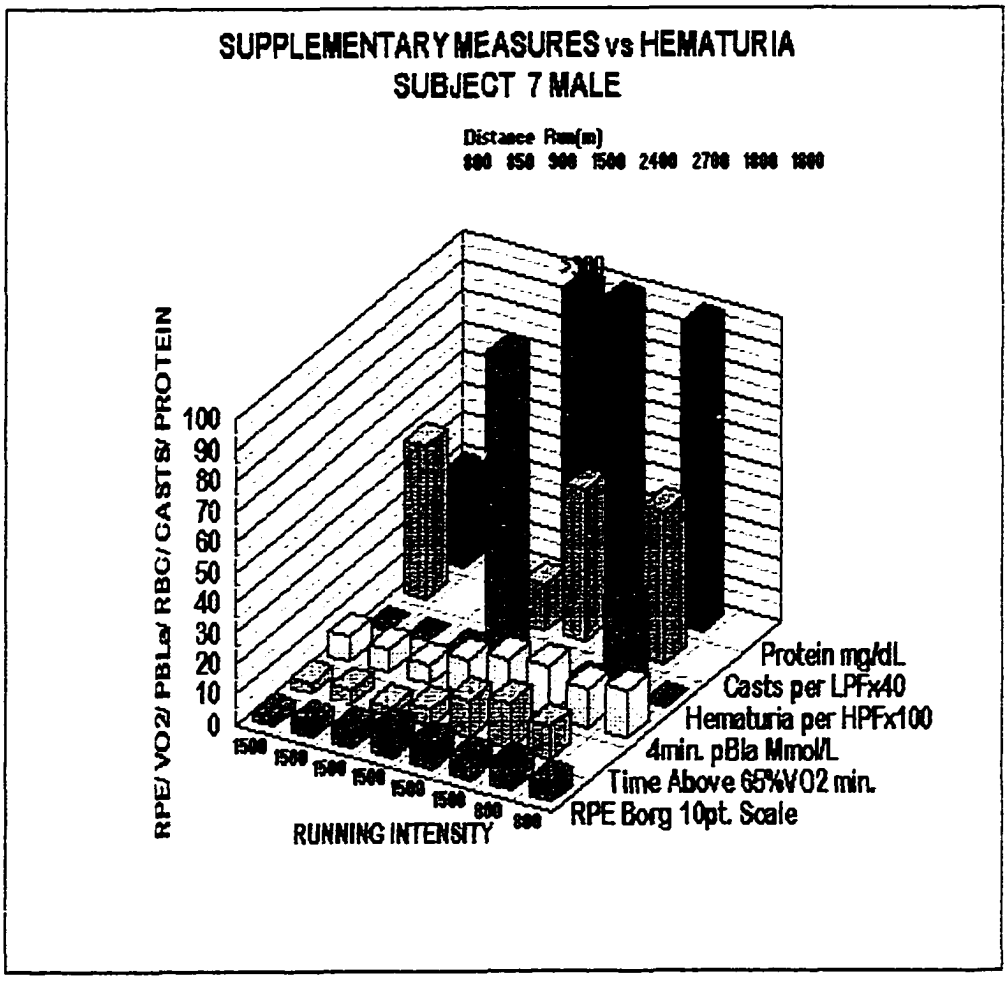

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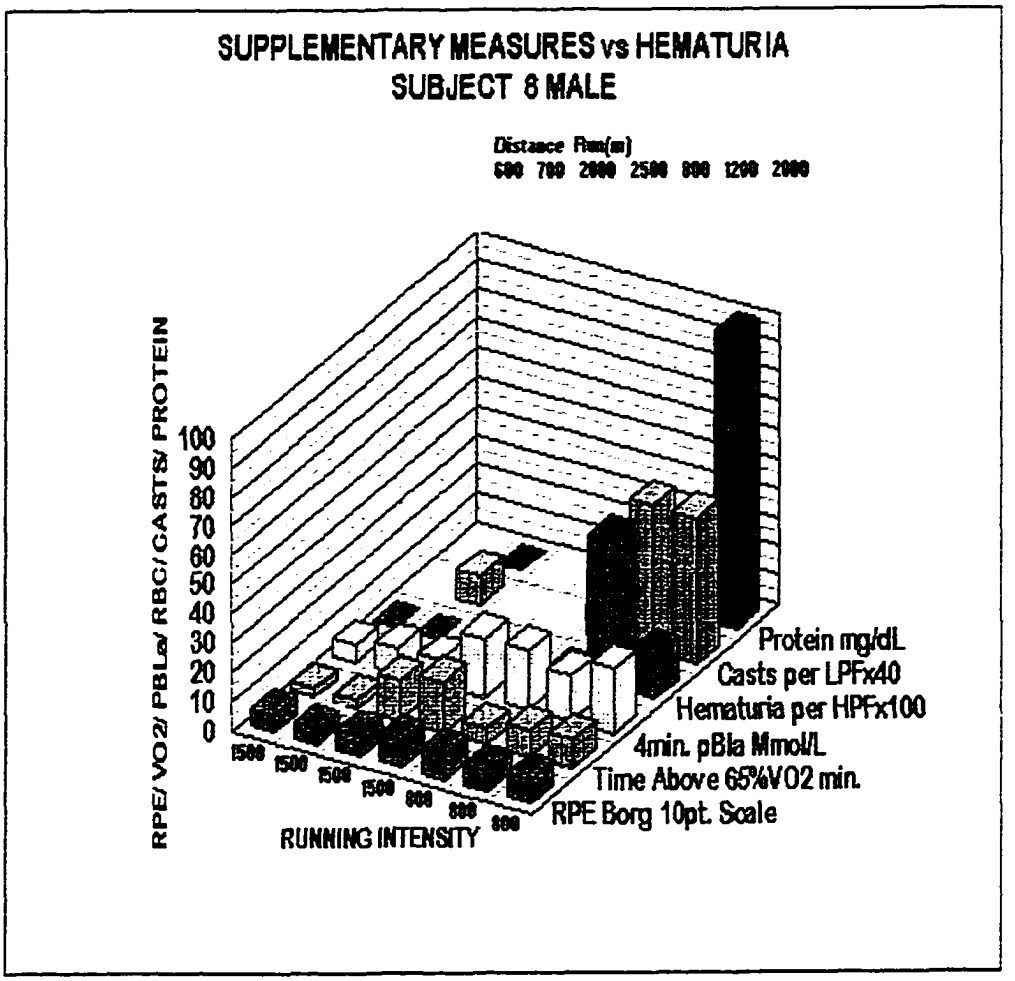

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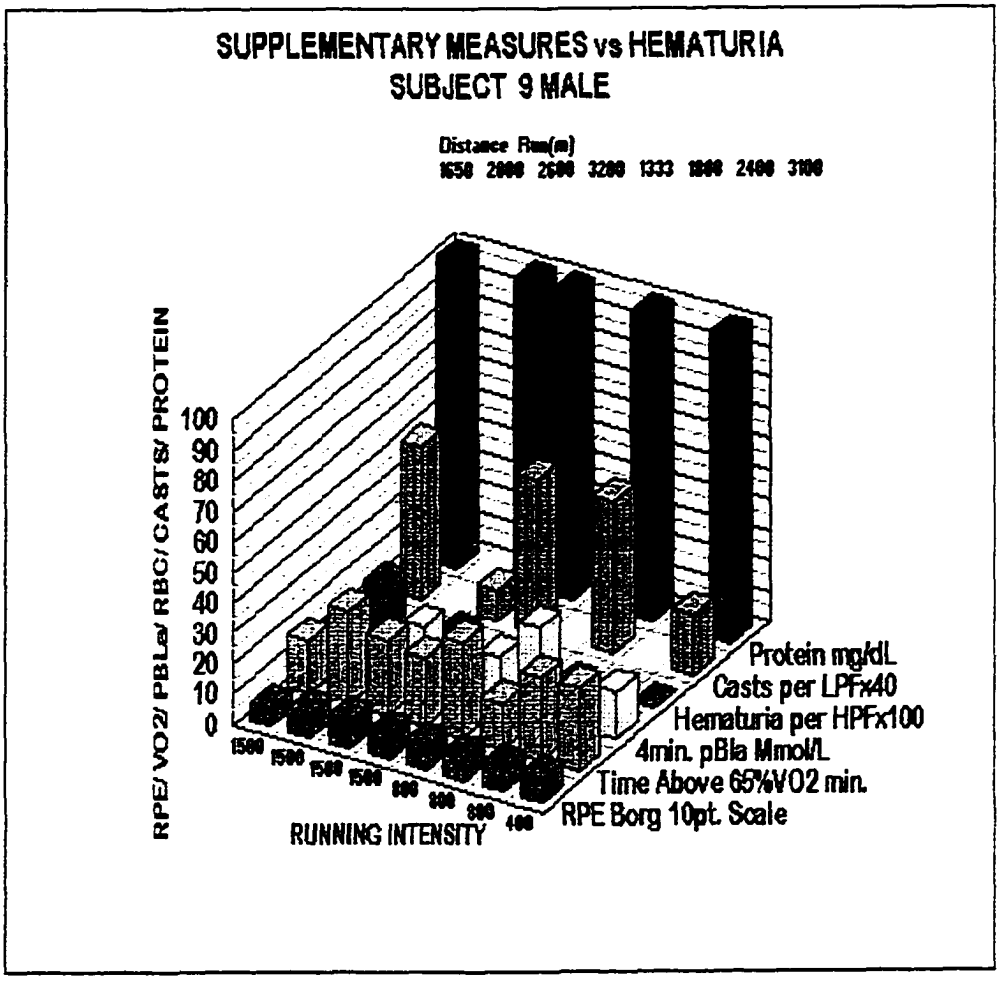
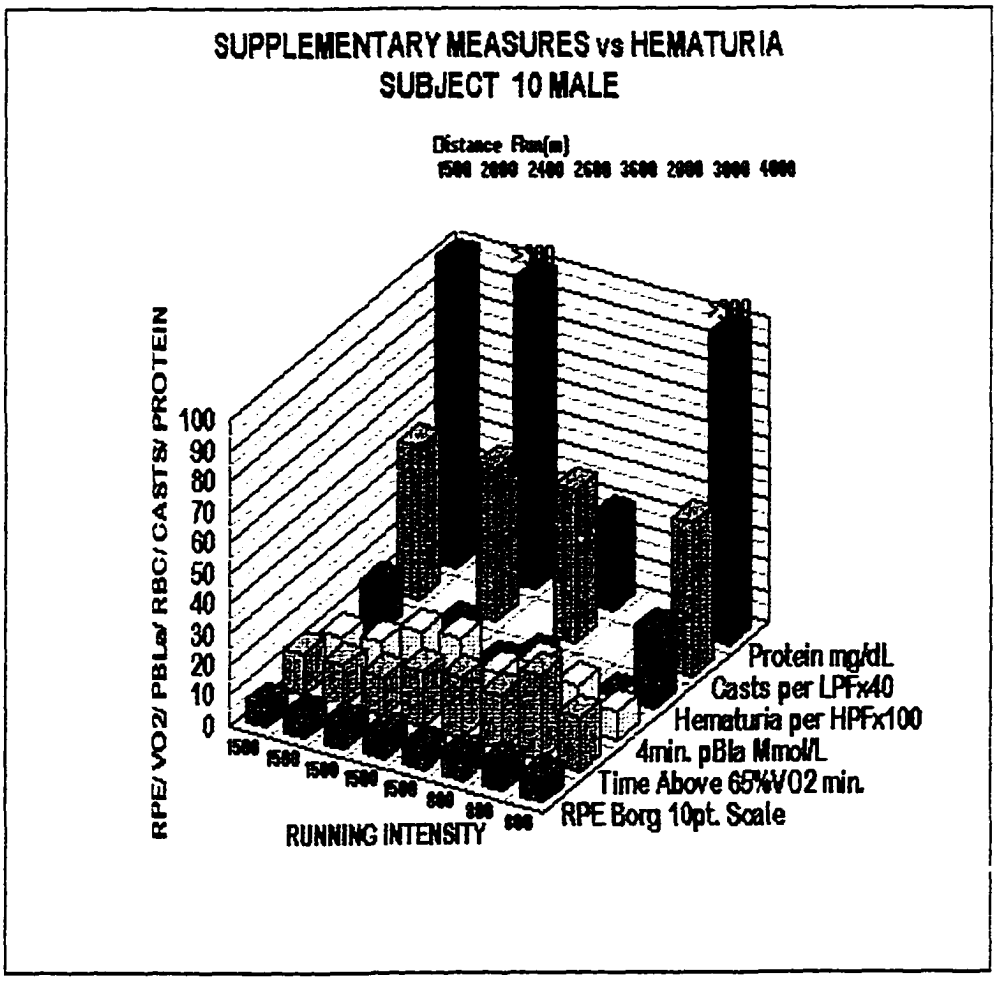


APPENDIX A. Subject 10.



APPENDIX B. Athlete Training Schedule

-1995-

HEMATURIA STUDY

DATE	LOCATION	PACE	WORKOUT	OTHER
JAN 22	ROAD	EASY	LONG RUN	
JAN 23	ROAD	10,000M	AT. 14 OF 25 OR 14 OF 45	
JAN 24	TRACK	1,500M	LADDER 1,2,3,4,3,2,1	DATA COLLECTION
JAN 25	POOL			
JAN 26	TRACK	800M	3(3X200)	DATA COLLECTION
		3000M	500,1000,1500, 1000,500	
JAN 27	**REST DAY**			
JAN 28	TRACK	RACE	CONTIN. RELAY 5X2LAP 5X1LAP	
JAN 29	ROAD	EASY	SHORT RUN	
JAN30	ROAD	10,000M	AT.13 OF 25	
JAN 31	TRACK	1,500M	2(3X400)	DATA COLLECTION
FEB 01	POOL	VERY LIGHT		
FEB 02	TRACK	800M	400+200	DATA COLLECTION
		3000M	2X500	
FEB 03	**TRAVEL & LIGHT JOG**			
FEB 04	TRACK	RACE	CARGILL GAMES	TRACK MEET
FEB O5	ROAD	EASY	RECOVERY RUN	
FEB 06	ROAD	10,000M	AT. 12 0F 25 0R 12 OF 45	
FEB 07	TRACK	1,500M	LADDER 1,2,3,2,1 LAPS	DATA COLLECTION
FEB O8	POOL			

FEB 09	TRACK	800M	1(3X200)	DATA COLLECTION
		3000M	1(3X2LAPS)	
FEB 10	**REST DAY PART 1 WARM UP**			
FEB 11	TRACK	RACE	LAST CHANCE QUALIFIER	TRACK MEET
FEB 12	ROAD	EASY	LONG RUN	
FEB 13	ROAD	10,000M	AT. 13 OF 25 OR 13 OF 45	
FEB 14	TRACK	1,500M	2-3(3X400)	DATA COLLECTION
FEB 13	POOL			
FEB 16	TRACK	800M	6+2+2+2+4+2+4 LAPS	DATA COLLECTION
		3000M	500,1000,1500, 1000,500	

AT: Anaerobic threshold run done at 10,000 metre race pace. 14 of 25 means that the middle 14min. of a 25min run should be done at AT.
LADDER: The number of repeats increase by one lap then decrease by one lap.
EASY: the running pace is at a level in which a conversation can be carried out.
PACE: Represents the athletes target running pace based on past performance and reasonable performance expectations for the competition season.
POOL: A running workout done in the pool.

10min. swim
3x30sec. run on the spot with 45sec. easy recovery
3x60sec. run on the spot with 45sec. easy recovery
3x90sec. run on the spot with 45sec. easy recovery
15min. deep water run 'A', 'B','C'.
A= high knees
B= long strides
C= heels to buttocks.

APPENDIX C. Sample Training Log

SAMPLE TRAINING LOG BOOK:

LAKEHEAD UNIVERSITY
-1995-
HEMATURIA STUDY

GARETH JONES: 345-1459 or 343-8187

NAME: DATE:

TRAINING ACCOMPLISHED:

TOTAL METRES: TOTAL TIME:

SHOES USED: DRUGS:
RPE: 0.5 1 2 3 4 5 6 7 8 9 10 MENSES: YES/NO

COMMENTS:

APPENDIX D. Consent Form

LAKEHEAD UNIVERSITY
Department of Kinesiology

Dr. Ian Newhouse 343-8074
Gareth Jones 343-8187 or 345-1459

PARTICIPANT CONSENT FORM

I _____ understand the conditions of involvement as a subject in this study. I have read and understood the covering letter of the study entitled " The Incidence of Hematuria with Middle Distance Track Running Interval Training", by Dr. Ian Newhouse and Gareth Jones. I am aware that I will have to submit urine and blood lactate samples before and after my running workouts over a four week period. I also agree to keep a detailed training log during the testing period. I also understand that I am free to withdraw my consent at any time.

Publication of the results will not reveal subject identity as subjects will be referenced by number. Subjects will be notified of positive urinalysis and will be responsible for notifying their personal physician. Please feel free to contact Dr. Ian Newhouse or Gareth Jones if you have any questions concerning the study.

I have read and understand the explanation of the purpose and procedures for this study and agree to participate.

_____

Signature of Participant
Date

_____

Signature of Witness
Date

_____

Signature of Researcher
Date

APPENDIX D. Cover leter.

LAKEHEAD UNIVERSITY
Department of Kinesiology
Dr. Ian Newhouse 343-8074
Gareth Jones 343-8187 or 345-1459

Dear athlete,

Thank you for volunteering to participate in a study concerning the "The Incidence of Hematuria and Middle Distance Track Running Interval Training".

Hematuria refers to the loss of red blood cells via the urine. A possibility exists that the red blood cells may be released in the urine following intense, physical exertion due to a combination of hypoxic conditions incurred by the kidneys and trauma to the bladder and kidneys. A potential result of chronic hematuria is iron deficiency while more severe losses may be a sign of acute renal failure. This study will analyse the incidence and qualitative significance of hematuria among a small population of trained track runners.

Subjects will be monitored for hematuria over a four week period of normal interval training. Urine and blood lactate samples will be collected and analysed for the presence of hematuria prior to and immediately following the workout. Baseline urine samples will screen for hematuria, not attributed to the training session, such as female menses or an underlying disease related disorder. A resting blood lactate sample will be taken prior to exercise to ensure that the subject is sufficiently rested by providing a resting blood lactate sample of less than 2.0 Mmol/L. The subject will then continue with his/her normal training.

A second blood lactate sample will be taken 4min. after the final running interval to measure the peak blood lactate along with a verbal rating of perceived exertion. Heart rate will also be recorded using a Vantage XL heart rate monitor (Polar Inc.) These measures will give an indication of how hard the subject has exerted themselves during the workout. Following a controlled warm down the subject will submit a second urine sample which will be analysed for hematuria using reagent strips. Positive samples will be taken to Port Arthur General Hospital for microscopic analysis. Three red blood cells per high power field is indicative of hematuria. Urine sampling will continue with each emptying of the bladder, until the sample provides a negative result for hematuria.

By observing the incidence and quantitative significance of hematuria, following a variety of high intensity, interval sessions will help in identifying those workouts which promote the greatest loss of red blood cells. Recommendations regarding the appropriate training required by track runners in order to prevent anemic symptoms, due to red blood cell loss, will hopefully be inferred from this study.

Sincerely,
Gareth Jones

APPENDIX E: Borg Rating of Perceived Exertion

RATING OF PERCEIVED EXERTION

BORG SCALE

0	**NOTHING AT ALL**
0.5	**VERY,VERY WEAK**
1	**VERY WEAK**
2	**WEAK**
3	**MODERATE**
4	**SOMEWHAT STRONG**
5	**STRONG**
6	
7	**VERY STRONG**
8	
9	
10	**VERY, VERY STRONG, MAXIMAL**

from: Borg,G.A. (1982). Psychological bases of perceived exertion., Medicine, Science, Sports & Exercise, 14:377-387.

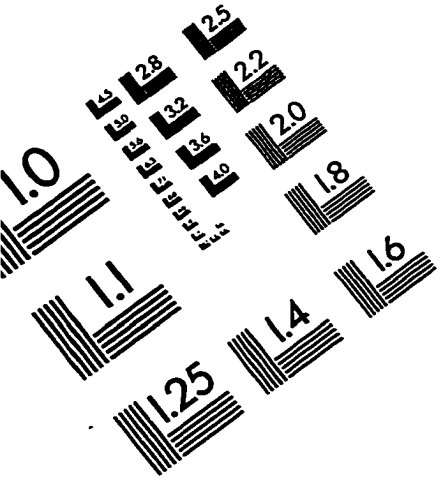
APPENDIX F: Treadmill Test Protocol

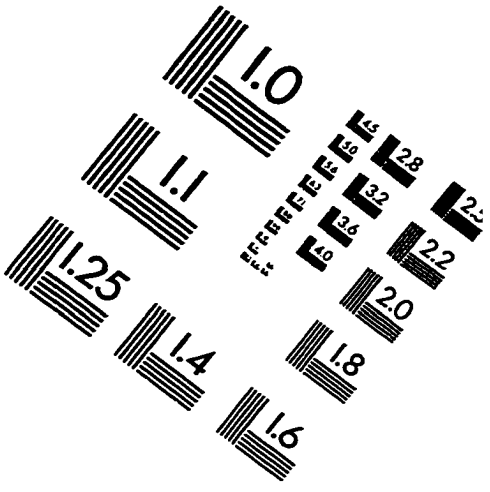
VO_2 max. TREADMILL PROTOCOL

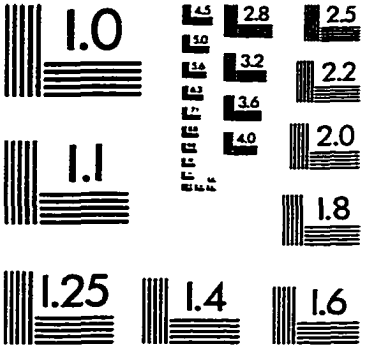
TIME (MIN)	SPEED(mph)	%GRADE OF SLOPE
START	6	0
1.0	6.5	0
2.0	7.0	0
3.0	7.5	0
4.0	8.0	0
5.0	8.5	0
6.0	9.0	0
7.0	9.5	0
8.0	10.0	0
9.0	10.5	0
10.0	11.0	0
11.0	11.0	2
12.0	11.0	4
13.0	11.0	6

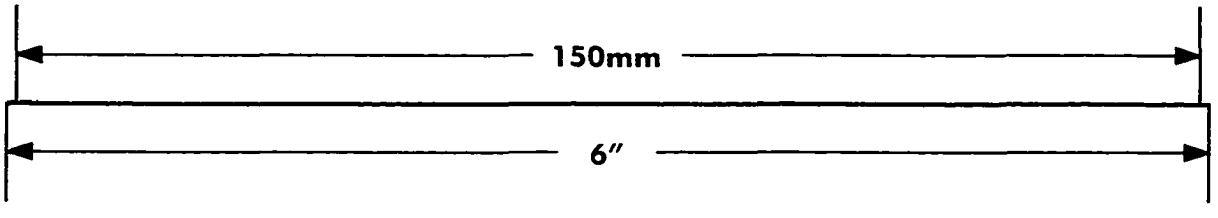
* The slope increases two workloads past anaerobic threshold or the point in which FEO_2 and $FECO_2$ cease to have a linear relationship.

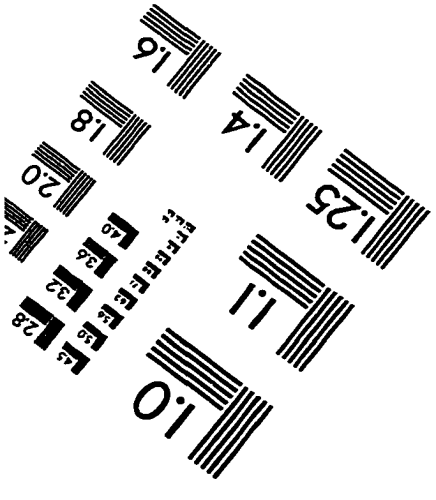
IMAGE EVALUATION TEST TARGET (QA-3)

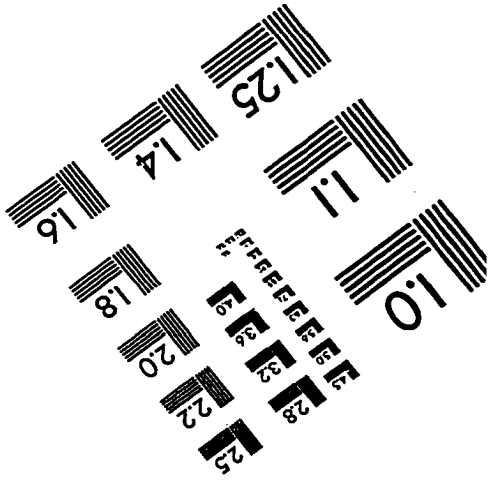












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