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EFFECT OF SUPPLEMENTARY PHOSPHATE
ON WORK PERFORMANCE

Thesis for the Degree of M. A.
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Gale E. Miklos

1953

This is to certify that the
thesis entitled
**Effect of Supplementary Phosphate
on Work Performance**

presented by

Gale E. Mikles

has been accepted towards fulfillment
of the requirements for

MA. degree in Physical Education


Henry J. Montoya
Major professor

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**EFFECT OF SUPPLEMENTARY PHOSPHATE
ON WORK PERFORMANCE**

**By
Gale E. Mikles**

A THESIS

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THESIS

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CHAPTER I

THE PROBLEM

In the past decade experimental work has shown that phosphate has a key role in the metabolism of muscle. Organic phosphate, in the form of Adenosine triphosphate is now regarded as the compound responsible for energy release and muscle contraction. A supply of creatine phosphate in the muscle is kept as a ready supply of phosphate. Phosphate compounds also play many other important roles in the metabolism of muscle.

There have been few controlled studies concerning this dietary supplement on work performance. The results of dietary studies and their effect on physical performance have been conflicting. Ancel Keys¹ in a summary of the literature states that the effects of diet supplements on muscular work is not clear or definite.

From a coaching and training stand point the increase of performance and postponement of fatigue is of utmost importance. The usefulness of dietary phosphates in this connection is the principal purpose of the proposed study. Any fundamental knowledge gained through this experiment might also have implications in combating fatigue in

¹Ancel Keys, "Physical Performance in Relation to Diet," Federation Proceedings, 2:164-176, September, 1943.

industrial workers, and other types of labor requiring considerable amount of energy expenditure.

Statement of the problem. The purpose of this problem is to find the effect of a dietary supplement of five grams of primary sodium phosphate on the work performance of two men, and to compare the effects of different periods of time elapse between consumption of phosphate and physical testing.

Importance of the study. If it could be proven that dietary phosphates could effect greater work performance in a well nourished, healthy individual, it would prove of great interest to people in athletics and the coaching profession. It might well be important to many types of professional workers, concerned with body stress.

Workers in industry could possibly take phosphates to ward off fatigue towards the end of the day or during overtime hours. Men in the armed forces might find cause for the use of phosphates during forced marches or extended periods of combat.

Sources of data. The data are taken from case studies of two men, ages twenty-four and thirty-one. Both men were in good physical condition and were receiving a normal diet.

Limitations of the study. 1. There was no attempt to control the type of diet or amount daily consumed. Since under actual day to day conditions, the diet of any group of athletes cannot be controlled, no attempt at control was made here.

2. No attempt was made to control the temperature or humidity in the room in which the tests were run.

3. Factors such as sleep and amount of daily activity before testing could not be completely controlled.

4. Since only two individuals were tested the results must be regarded as being biased due to the use of a selected sample.

5. Only one intensity of exercise was used in the testing.

6. The dosages were given orally with no effort to preordain the amount finally assimilated in the body.

CHAPTER II

REVIEW OF LITERATURE

In the chemistry of muscle it has been demonstrated that a number of substances play an important part in muscle activity. An integral part of many of these substances is phosphorus.

The standing concept of muscle activity up until 1926 was based on the chemical and energy exchanges between carbohydrate and lactic acid. It was thought that lactic acid formation was the only factor causing muscular contraction and that energy for contraction was derived from lactic acid production and glycolysis. This does not mean to imply that experiments done up until this time were incorrect. No theory of muscle contraction had been postulated. Therefore, many of the experiments were factual even though the theory was incomplete.

Embden² found that there was a liberation of phosphorus in the muscle during activity. In his tests with rested and fatigued muscle, he found that phosphorus diffused more rapidly into Ringers solution from the fatigued

²A. V. Hill, "The Revolution in Muscle Physiology," Physiology Review, Jan., Vol. XII, 1932. p. 57, citing G. Embden and E. Adler, "Über die physiologische Bedeutung des Wechsels des Permeabilitätszustandes von Muskelfasergrenzschichten," Hoppe-Seyler's Zeitschrift für Physiologische Chemie, Berlin and Leipzig, 118:1-49, 1922.

muscle. He attributed this to a change in permeability of the muscle surface. He did not recognize it as the new appearance of inorganic phosphorus within the muscle.

He came closer to the present-day conception in another study.³ He stated that the immediate energy for anaerobic work was derived from some unknown colloidal chemical reaction. He also claimed that at least part of the lactic acid was formed after muscular contraction. Both these claims were to be accepted later, but at the time were believed to be wrong. The colloidal chemical reaction was ultimately to be the key to the whole problem of muscular activity.

Working from a different approach, Teigs⁴ also found that creatine diffused faster from a tired muscle than from a fresh one. He discovered that oxygen would stop this excess diffusion. Teigs also made the discovery that creatine became more alkaline during muscular contraction.

It was then known that phosphorus compounds had some special function in muscle activity, and although it was

³A. V. Hill, Op. Cit., p. 60, citing G. Embden, H. Hirsch-Kauffman, E. Lehnartz and H. J. Deuticke, "Über den Verlauf der Milchsäurenbildung beim Tetanus," Hoppe-Seyler's Zeitschrift für Physiologische Chemie. Berlin and Leipzig, 151:209-231, 1926.

⁴O. W. Teigs, "The Function of Creatine in Muscular Contraction," Australian Journal of Experimental Biology and Medical Science. 2:1-22, 1925.

known that creatine was present in large amounts, no one had identified it as an important factor. It had begun to be suspicioned that lactic acid was not the only causal factor in muscle contraction but was at least partially formed after contraction.

The Eggletons⁵ then showed that when a muscle was stimulated, a material that they called phosphagen (creatine phosphate) broke down, and if oxygen were present it was quickly restored. They also concluded that the content of Creatine phosphate was greater in skeletal muscle than in smooth muscle. This indicated that the slow muscles needed less creatine phosphate because they did not use it rapidly.

In a similar experiment the same conclusions were reached by Fiske and SubbaRow⁶. They also showed that the compound when broken down yielded creatine and phosphoric acid. They believed that its breakdown was necessary for effecting a buffer within the muscle. This fitted in nicely with Teigs discovery of an alkaline reaction during muscular activity.

⁵P. Eggleton, and G. P. Eggleton, "Further Observations on Phosphagen," Journal of Physiology. 65:15-24, 1928.

⁶C. H. Fiske and Y. SubbaRow, "The Nature of the 'Inorganic Phosphate' in Voluntary Muscle," Science. 65:401, 1927.

Nachmansohn⁷ then showed that after muscular activity with resulting creatine phosphate breakdown; some of the creatine phosphate was re-combined rather rapidly, even under anaerobic conditions. This recombination was later attributed to glycolysis and the operation of the tricarboxylic cycle.

The modern conception of high energy phosphate might well have had its beginning in the work of Meyerhof and Suranyi⁸. They were able to find a considerable amount of heat liberated by the hydrolysis of creatine phosphate. This heat was measured at 12,000 calories per mole of creatine phosphate broken down.

Then when Lundsgaard⁹ published his papers, the role of creatine phosphate in muscle contraction became understood. He had been able to suppress the resynthesis of creatine phosphate through glycolysis by poisoning the

⁷A. V. Hill, Op. Cit., p. 58, citing D. Nachmansohn, "Über den Zerfall der Kreatin phosphorsaure im Zusammenhang mit der Tätigkeit des Muskels," Biochemische Zeitschrift, Berlin. 216:73-97, 1928.

⁸W. F. Mommaerts, Muscular Contraction, Interscience Publishers, Inc., New York, p. 19, 1950., citing O. Meyerhof and J. Suranyi, "Über die Warmetonungen der chemischen Reaktionsphasen im Muskel," Biochemische Zeitschrift. 191:106-124, 1927.

⁹A. V. Hill, Op. Cit., p. 66, citing a series of three papers by E. Lundsgaard, (taken from the last) "Über die Energetik der anaeroben Muskelkontraktion," Biochemische Zeitschrift, 233:322-343, 1931.

muscle with iodoacetate.

A normal muscle gives about four hundred twitches before exhaustion, but the poisoned muscles went into contracture after one hundred twitches. The muscle could not be stimulated nor could it recover, even in oxygen. It was then believed that creatine phosphate could furnish all the energy needed for normal muscle contraction. With the poisoning of the muscle, contractile activity continued until the supply of creatine phosphate was exhausted. At no time during contraction was there any lactic acid production. There was no anaerobic reproduction of creatine phosphate.

In 1929, Embden¹⁰ had identified adenylic acid in muscle. Lohmann¹¹ had already discovered that a trichloroacetic acid extract of muscle contained a substance, which upon hydrolysis, yielded inorganic phosphate with characteristics of an inorganic pyrophosphate. Upon study of the natural compounds, he found a decrease after contractions, and a total disappearance after mincing or in rigor. However, when inorganic pyrophosphate was added to muscle

¹⁰A.V. Hill, Op. Cit., p. 57, citing G. Embden and G. Schmidt, "Über Muskeadenylsäure und Hefeadenylsäure," Hoppe-Seyler's Zeitschrift für Physiologische Chemie, 181:130, 1929.

¹¹A.V. Hill, Ibid, p. 60, citing K. Lohmann, "Über das Vorkommen und den Umsatz von Pyrophosphat im Zellen," Biochemische Zeitschrift, 203:172-207, 1928.

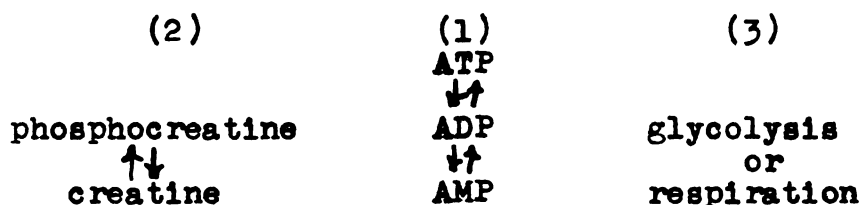
juice it did not behave as did the natural compound.

In later studies, Lohmann¹² found that pyrophosphate and adenylic acid are normally combined in muscle to form adenosine triphosphate(ATP). It was also discovered that there apparently was no device that would dephosphorylate creatine phosphate(CP) directly. The dephosphorylation seemed only to take place through the mediation of adenosine diphosphate(ADP) to adenosine triphosphate(ATP). ATP thus became associated with the primary process of contraction. The experiment thus showed the sequence of events during muscular contraction. The decomposition of ATP occurred first and was reversed by the breakdown of creatine phosphate. ATP thus acted as the primary energy yielding instrument for muscular contraction with creatine phosphate acting as a store of reactive phosphate groups.

It had then been established that ATP created the trigger mechanism, and supplied the energy for muscular contraction, and that in the required reaction ATP lost one phosphate radical. The chemical cleavage released approximately 11,000 calories per mole. The resulting ADP may be further broken down to adenylic acid(AMP). The ADP or AMP formed then reacted with creatine phosphate to reform ATP.

¹²A. V. Hill, Op. Cit., p. 60, citing K. Lohmann, "Über das Vorkommen der Adenin-Nukleotide im den Geweben," Biochemische Zeitschrift. 272:24, 1934.

The processes of glycolysis and respiration regenerate these energy rich phosphate compounds after their depletion. Mommaerts¹³ represented these events by the following cycle:



During activity, reaction (1) proceeds in the sense of splitting. This is reversed very rapidly by (2), so that ATP is decreased measurably only after a significant diminution of phosphocreatine. The final reversal of both (1) and (2), but primarily of (1), is effected by (3), but this may lag behind. In the case of respiration, no lactate is formed intermediately.¹⁴

This paper will not take up the involved reactions concerning glycolysis and tricarboxylic cycle. It will only mention its functions. The tricarboxylic cycle concerns the oxidation of fats (Ketone bodies), carbohydrate (Pyruvic acid), and amino acids (Keto acids) as well as the breakdown products of glycogen. These oxidations all require phosphorus in some form. During strenuous exercise, most of the ATP supply comes from this anaerobic source.

It should be kept in mind that respiration takes care of ATP production unless the body indulges in rather severe

¹³W. F. Mommaerts, Muscular Contraction, Interscience Publishers Inc., New York. p/ 19, 1950.

¹⁴Ibid., p. 19.

exercise. Very little lactic acids is formed under these conditions. Under conditions of muscular stress, however, ATP is used up much faster than the oxidative processes can form it. Under these conditions most of the ATP must be provided by the rapid anaerobic glycolysis of glycogen. Lactic acid and pyruvic acid accumulate when their rate of production by glycolysis exceeds the capacity of the muscles to oxidize them in the tricarboxylic cycle. High content of lactic acid and inorganic phosphates, as well as a low content of glycogen, ATP, and creatine phosphate is characteristic of exhausted muscle.

Much of the work done on the actual mechanics of muscle contraction has been done by Dr. Albert Szent-Gyorgyi¹⁵. He has taken the muscle protein myosin apart and found it to be not one protein, but two. The particles that were threadlike in appearance he continued to call myosin, but the globular particles of the protein compound was renamed actin. The contractile element of muscle seemed to consist of these two new proteins in combination with the enzyme, adenosine triphosphatase(ATPase). The two proteins reacted to form actomyosin. They were believed to be the fiber of muscle. ATP is adsorbed upon the myosin

¹⁵A. Szent-Gyorgyi, Nature of Life, A Study of Muscle. Academic Press, Inc., New York. p. 39, 1948.

ATP is very strongly linked to myosin and represents a very high energy bond. The ATPase is combined with the actomyosin-ATP complex. As the muscle is stimulated, the enzyme breaks down the ATP which in turn effects the energy release causing muscle contraction. The fact that creatine phosphate broke down at this point, and was coincidental with relaxation, seemed to indicate a specific function in relaxation. However, this was not clear.

Szent-Gyorgyi¹⁶ summarized the muscular contraction and relaxation process with the following symbols:

Rest: actin myosin-ATP!
Excitation: actomyosin-ATP!
Contraction: actomyosin-ATP c
Relaxation: actomyosin-ATP $\rightleftharpoons$ actomyosin ADP + phosphate
actomyosin-ADP + CP $\rightleftharpoons$ actomyosin-ATP! c
actin + myosin-ATP!

In this summary, the relaxed state was designated by r, the contracted state by c and the high energy bond by an exclamation mark.

The best known work involving phosphate supplement with humans as subjects was done by Gustav Embden¹⁷ during

16A. Szent-Gyorgyi, Op. Cit., p. 122.

17 G. Embden, E. Grafe, and E. Schmitz, "Über Steigerung der Leistungsfähigkeit durch Phosphatzufuhr," Hoppe-Seyler's Zeitschrift für Physiologische Chemie, 130:67-107, 1921.

the first World War. He tested German soldiers on an ergostat which they operated at 1800 revolutions per hour. The soldiers operated under very closely controlled conditions. Upon feeding a supplement of primary sodium phosphate there was noted a sizable increase in performance.

During the tests, the soldiers were given placebos in order to control psychological factors and to check on phosphate carry over. The soldiers were never informed of the time they achieved or even of the purpose of the experiments.

Embden also ran some largely subjective experiments with whole battalions of soldiers on long forced marches. One group of men was given phosphate in their drinking water. Another group was given nothing. The two bodies of men marched at a good distance apart so that the men themselves were not aware of any differences.

The marchers receiving the phosphates apparently did not tire nearly as rapidly as those who did not receive phosphates. There was a decrease in perspiration and high spirits prevailed in the phosphates group long after the other group was silent and had begun to tire.

These observations were also made by by-standers who knew nothing of the experiment.

Embden also showed results with miners whose production increased after taking phosphates.

Admittedly, there were factors and conditions during the work with the soldiers and miners that were not under control. However, one is forced to note a trend towards greater physical endurance due to the phosphate supplement.

During the National A.A.H.P.E.R. Convention in Dallas, Texas, in 1950, Arther Steinhaus reported a subjective experiment he had run on basketball players at the University of Illinois, Chicago, Illinois. On the day that a phosphate supplement was given, the players seemed more active and tired less quickly. An experienced coach might easily observe a change in player performance. Here again would seem to be a trend toward superior performance and greater endurance when phosphate supplement was administered.

The work of Embden involved sustained activity for a long period of time. Work rate was relatively low, whereas in most other activities, the rate of work is high. This is an essential difference in Embden's work and the present work.

CHAPTER III

METHODOLOGY

The experimental subjects. This experiment is of the case study type. Only two men were tested, the author and another member of the Michigan State College Physical Education staff. The ages of the men were twenty-four and thirty-one. Both were active in recreational sports and considered to be healthy and in good physical condition.

Equipment used in testing. The piece of equipment used for measuring work performance, was a friction type bicycle ergometer made from the design by Karpovich¹⁸. This type of ergometer was set with weights pulling on the bottom end of a friction belt passing around the bicycle wheel. As the wheel warmed up through contact with the belt, slippage occurred. A scale connected at the top of the belt registered this slippage in ounces, and one ounce weights were added to the weights on the bottom of the belt to compensate for the change.

The bicycle was equipped with a speedometer and a revolutions counter.

¹⁸P. Karpovich, "A Frictional Bicycle Ergometer," Research Quarterly, 21:210-215, 1950.

Feeding of the phosphate. In order to prevent the subjects knowing what they were taking, some preparations were made. A chart was made showing the identity of the dosage, and the time elapsed between consumption and performance. Each dose was given a number.

The phosphate, or sugar (placebo), was put into capsules for consumption. The capsules were put into small prescription envelopes and properly marked with the dosage number and the time elapse to be observed.

Sodium phosphate crystals, upon slight pounding, were reduced to about the same crystal size as sugar. Once in the capsules, the two substances looked very similar, so that the subjects could not tell what they were taking.

A schedule for feeding the supplement was determined. This schedule showed whether the capsules taken contained five grams of phosphate or five grams of sucrose. (See Chart I.) Placebos of sucrose were given according to schedule to control psychological and conditioning factors as well as to show the carry-over effects of the phosphate.

Since it was desired to know when the phosphate had its greatest effect after consumption, the envelopes were marked for taking at two, three, five, and seven hours before testing on the bicycle.

A list of high phosphate containing foods was made up and a record was kept of the amounts of the foods con-

sumed daily by the subjects. This was done to make sure that neither of the men was nutritionally deficient in the element being provided.

Experimental procedure. The men were tested five days a week during the period from two p.m. to six-thirty p.m.. The bicycle was ridden at the speed of twenty miles per hour at four pounds constant pressure. The rider was timed with a stop watch. When the rider could no longer hold the speed at a constant twenty miles per hour, the time was recorded. Sprocket revolutions were also recorded for a positive check of the speed maintained during the run. Any other pertinent information was also recorded. The two men took no strenuous exercise before being tested.

The tests of the two subjects were charted. (See Chart I.) The performances are shown along with the true identity of the capsule taken before the test, and the period of time before testing. An attempt was made to correlate the different performances with the material taken as well as the period of time elapsed before performance.

Variables and constants. There were two variables in the experiment:

1. The period of time elapse between taking the phosphate and actual performance. There were four

different time periods of two, three, five, and seven hours. This was done to see if the time element influenced phosphate action on performance.

2. Placebos containing sucrose were given instead of phosphate at definite intervals. It was intended to control psychological factors as well as physical conditioning and to show phosphate carry-over.

The constants were as follows:

1. The bicycle was always ridden at twenty miles per hour with four pounds of weight resistance.

2. The amount of phosphate or sugar dosage was always five grams.

CHAPTER IV

RESULTS AND DISCUSSION

Chart I was plotted from the raw data that appears in Table I. The means of the different hour period run times were also plotted.

The data in both cases showed a steady rise in conditioning throughout the testing. This fact was apparent even though both subjects had undergone an untimed conditioning period of three months before the phosphate feeding started. The bicycle was ridden three times a week during the pre-feeding training period. The training period where a record of times were kept was three weeks long.

Chart I shows that subject G. M. had the majority of his best times on phosphate days. In every case where good timings were recorded on placebo days, these days were immediately following phosphate days. This would seem to indicate a phosphate carry-over. The means of each time period show that the average phosphate run was longer in all cases than the placebo runs. This was quite noticeable in the three and five hour periods, but the two and seven hour periods did not show a great difference. It was apparent that the phosphate was most effective when taken three to five hours before riding.

Subject H. M.'s times showed a partial reversal of

TABLE I
DAILY PERFORMANCE RECORD

Date	H. M.			G. M.		
	Feeding	Time	Revolutions	Feeding	Time	Revolutions
5/28/52	o	1:35	159	-----	-----	-----
29	o	1:20	131	*	4:21	441
30	-----	-----	-----	*	3:47	378
31	-----	-----	-----	-----	-----	-----
6/1/52	-----	-----	-----	-----	-----	-----
2	*	1:40	166	o	5:45	583
3	o	1:37	163	o	6:01	625
4	o	1:46	175	o	5:27	554
5	o	1:34	156	*	4:03	429
6	*	2:06	206	o	7:24	738
7	-----	-----	-----	-----	-----	-----
8	-----	-----	-----	-----	-----	-----
9	*	1:47	174	o	5:33	547
10	*	1:44	172	*	5:56	593
11	-----	-----	-----	o	6:34	661
12	o	2:45	270	*	6:32	655
13	*	2:17	224	-----	-----	-----
14	-----	-----	-----	-----	-----	-----
15	-----	-----	-----	-----	-----	-----
16	o	2:20	233	*	4:23	435
17	o	1:45	175	o	5:30	557
18	o	2:14	223	o	4:18	435
19	*	2:25	237	o	4:19	433
20	-----	-----	-----	*	3:21	337
21	*	2:33	247	o	4:41	463
22	-----	-----	-----	-----	-----	-----
23	*	2:28	239	-----	-----	-----
24	o	2:19	232	o	5:18	510
25	o	2:50	280	o	4:58	496
26	o	1:45	175	-----	-----	-----
27	*	2:52	286	o	5:05	514
28	-----	-----	-----	-----	-----	-----
29	-----	-----	-----	-----	-----	-----
30	o	3:02	305	*	5:41	566
7/1/52	o	2:34	256	*	4:41	462
2	*	2:36	260	-----	-----	-----
3	-----	-----	-----	o	4:49	466
4	-----	-----	-----	o	5:01	519

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TABLE I
DAILY PERFORMANCE RECORD-CONTINUED

Date	H. M.			G. M.		
	Feeding	Time	Revolutions	Feeding	Time	Revolutions
7/5/52	o	2:15	220	o	6:03	645
6	-----			-----		
7	-----			-----		
8	-----			-----		
9	-----			-----		
10	*	2:47	272	-----		
11	*	2:56	291	-----		
12	-----			*	4:40	488
13	-----			-----		
14	o	2:33	250	*	4:51	470
15	o	3:02	336	o	5:21	532
16	-----			-----		
17	o	2:36	262	-----		
18	*	2:19	235	o	5:39	544
19	-----			o	6:08	618
20	-----			*	4:54	495
21	o	3:40		o	5:34	568
22	o	2:37	260	o	6:13	626
23	-----			o	6:53	691
24	-----			*	5:28	558

NOTE: This table should be read as follows: The dotted line indicates that subject did not ride on that day; the * indicates placebo; the o indicates phosphate.

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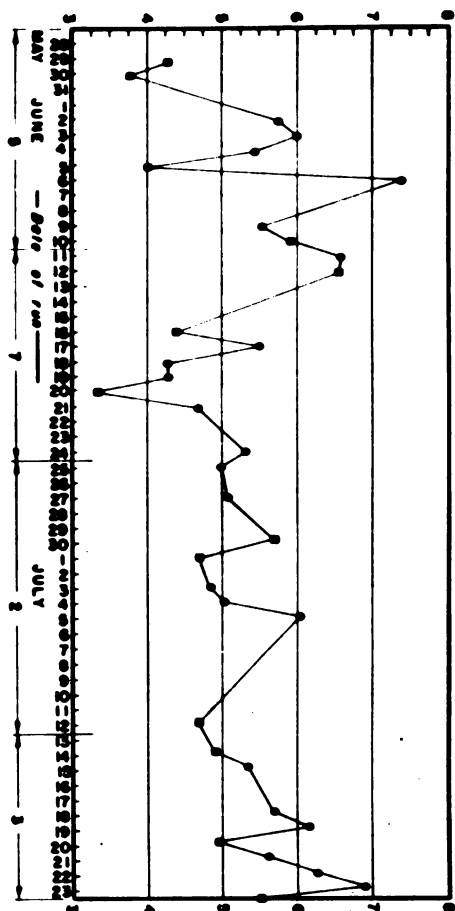
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EFFECT OF SUPPLEMENTARY PHOSPHATE ON WORK PERFORMANCE

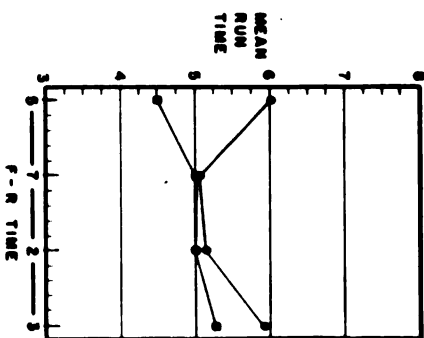
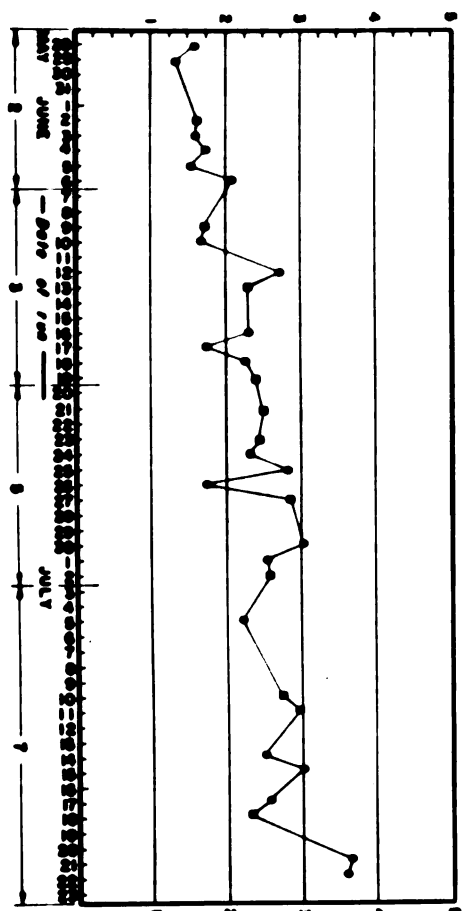
SPORTS RESEARCH LABORATORY
MICHIGAN STATE COLLEGE

—LEGEND—
● PHOSPHATE
● PLACED

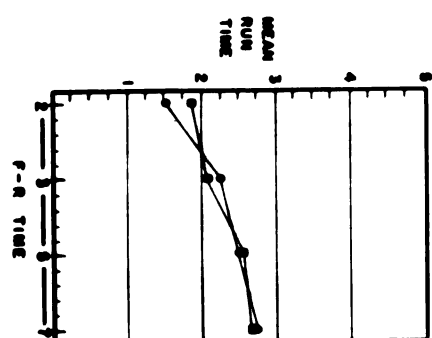
ERG-O-METER
RUN IN
MINUTES
G M



ERG-O-METER
RUN IN
MINUTES
H M



TWO HOURS BETWEEN
FEEDING AND RUN



subject G. M.'s efforts. All of H. M.'s best times were recorded on phosphate days. All but one of his lowest times were recorded after a phosphate feeding. The means times of the different time elapse periods showed that if phosphates had any effect on this subject, it was negligible. The phosphate means were below the placebo means in all cases, though the means were not far apart in any case. The results from these tests seemed to show only one positive effect; and that was a steady rise in conditioning.

Subject G. M.'s times showed a much more marked degree of variation than subject H. M.'s. G. M.'s runs were also longer than H. M.'s. This would seem to indicate the presence of a factor that this study failed to recognize or isolate.

During G. M.'s rides, when a phosphate day followed a placebo day, in every case the phosphate time was longer. There was no such pattern established during H. M.'s testing.

The general physical conditioning of both men proceeded at a faster rate during phosphate feeding than it had in the three months previous to testing. Another factor to be considered was the increase in riding from three to five days a week. This might well have increased the rate of conditioning by itself.

During the testing, both men experienced an occasional mild diarrhea; G. M. more often than H. M. The

condition was not serious.

The mental attitude of the subjects played an important part in the length of the ride. Both subjects felt that after a certain point, the ride was only extended as a result of mental fortitude. A rather odd point agreed upon by both subjects was that the length of the ride was not greatly determined by how the individual "felt" before riding. The feeding of phosphate apparently had no effect on the mental attitude of the two men.

Conditions of temperature and humidity were not controlled in this experiment. However, on concurrent days when weather conditions were similar, there was no noticeable difference in perspiration due to phosphate.

Throughout the experiment, H. M. attributed the termination of his time trial to tired or cramped muscles. The end of many of G. M.'s runs, however, were also marked by a decided shortness of breath.

From the nutritional standpoint it might conceivably be harmful to take overloads of phosphates over extended periods of time. The balance between calcium, phosphorus, and vitamin D could be affected, causing improper nutrition of bone.

A statistical analysis of the tests at the different time periods were made using the students "t" method. None of the time period differences were found to be significant

on the tests run on H. M. The periods of two and seven hours were found to be statistically insignificant in the trial run on G. M. The five hour difference was found to have a probability of from .05 to .02. These differences have a probability of .01 of occurring due to chance in the three hour period.

The speed measured as pedal revolutions per second was correlated with the length of the run. A correlation coefficient of .228 was found for H. M.'s runs and a correlation coefficient of $-.077$ was determined for G. M.'s runs. This was not significant in either case, indicating that there was no correlation between the length of the run and the speed of the run. The equipment was considered to have been run accurately with no appreciable error by the riders.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary. The purpose of this study was to find the effect of a dietary supplement of five grams of primary sodium phosphate on the work performance of two men, and to compare the effects of different periods of time elapse between consumption of phosphate and physical testing.

The data were taken from case studies of two men, ages twenty-four and thirty-one. Both men were in good physical condition and were receiving a well balanced diet.

The equipment used in testing was a friction type bicycle ergometer. Work done was measured by the length of time the subject rode the bicycle at the speed of twenty miles per hour with a weight resistance of four pounds. The men were tested five times a week. The testing was done in the afternoon during the hours between two p.m. and six-thirty p.m..

There were two variables in this experiment:

1. The period of time elapse between taking the phosphate and actual performance. There were four different time periods; two, three, five, and seven hours. This was done to see if the time element influenced phosphate action on performance..

2. Placebos containing sucrose were given instead of

phosphate at definite intervals. It was intended to control psychological factors as well as physical conditioning and to show phosphate carry-over.

There were also two constants in this experiment:

1. The bicycle was always ridden at twenty miles per hour with four pounds of weight resistance.
2. The amount of phosphate or sugar dosage was always five grams.

Conclusions. 1. Phosphate supplement caused no statistically significant difference in the period of time subject H.M. rode a bicycle ergometer, regardless of the period of time elapse between feeding and riding.

2. Phosphate supplement caused no statistically significant difference in the period of time subject G.M. rode a bicycle ergometer, when the period of time elapse between feeding and riding was two or seven hours. The probability for this difference was .05 to .02 when the period of time elapse was five hours. There was also a .01 probability for the difference in riding time when the period of time elapse was three hours.

3. Subjectively speaking, phosphate had no effect on the mental attitude of the individual riding the bicycle ergometer.

4. There was no noticeable decrease in perspiration due to phosphate.

5. A mild diarrhea was occasionally experienced, due to the phosphate feedings.

Recommendations. An attempt should be made to test at least thirty men in a sport in which they have had intensive training and experience. Track or swimming would be preferred. This would give a larger sample to work with and a set type of performance to analyse. If the men were in good physical condition when the testing was started it might be possible to do away with the variation in performance that so characterized the bicycle ergometer study.

1. It was difficult to get individuals who would stay throughout the study and give an all out performance whenever required.

2. A high level of motivation was very difficult to maintain. The degree of motivation is important and would be of great value if it could be measured.

3. Temperature and humidity should be controlled. This might be most easily accomplished in a swimming pool.

4. The testing should be done during the season of the sport. The men being tested would be more likely to have a standard diet and sleep a definite number of hours each night. Testing should be done before workout and at a set time each day.

Psychological problems caused by the attitude of the individual directing the feeding and exercise should be

studied, and so far as possible eliminated. The very fact that something is being fed causes the subjects to expect unusual things to happen.

APPENDIX

TABLE II
DAILY DIET RECORD-H.M.

Date	Food in Portions					Eggs
	Seeds	Flour foods	Meat	Milk	Milk Products	
5/28/52		8	3	6	1	
29	1	3	2	5	1	
30		No Record Kept				
6/2/52		4	2	5		
3	1	6	2	3	1	
4		4		3	3	1
5	1	6		6		1
6		7	2	3		2
9	1	5	4	2	1	
10		5	2	6	2	1
11		4	1	3		2
12	1	6	3	4		1
13		3	1	5		1
16		3	1	1	1	
17		4	4	5	1	1
18		6	2	6		
19	2	2	2	3	2	
20		3	1	2		
23		7	4	3		
24		4	3	5		1
25		2	2	2	2	1
26	1	5	4	6	1	
27	1	5	2	3	1	
28	1	3	3	3	1	
7/2/52		3	1	5		1
3	1	4	2	1	2	
4		3	1		1	3
5	1	7	3	4		
7	2	3	2	3		1
8		7	5	4		
9	1	3	3	3		1
11	1	4		3	1	2
14		3	2	4	2	1
15	2	3	2	6	1	
17	1	3	3	3		
18	2	3	1	5	1	2
21		4	3	4	1	1
22	2	3	1	4		

NOTE: The portions are figured on the basis of nutritional standards.

TABLE II
DAILY DIET RECORD-G.M.

Date	Food in Portions					Eggs
	Seeds	Flour foods	Meat	Milk	Milk Products	
5/28/52		3	2	5	2	
29	1		2	7	1	
30	2	1	3	4	1	
6/2/52	2		2	3	2	
3	2	2	3	5	1	
4	3	1	4	4		
5	1	2	3	5		1
6	1	2	2	4	2	
7		3	3	3		
9	3	2	4	4	2	1
10	2	3	3	5		
11	1	2	4	1	1	
12		3	3	4	1	
13	4		3	5	2	
14	1	1	2	5		1
17		4	3	5		
18	2	2	4	3	1	
19	1	3	3	5		
20	1	2	4	3		
21	3	3	3	6		
22			3	4	2	
23	2	2	2	5		
24	1	3	4	4		
25		4	3	5	1	
28	2	3	2	3		
7/2/52	3	3	2	5	1	
3		4	3	6		
4	1	5	4	4	2	
5	1	2	2	3		
6		4	3	5	1	
7	1	4	1	4		
10	3	2	4	3		
11	2	2	4	5		
12	2	2	4	2		
13	2		2	4	2	
14		4	3	4		
15	3	3	2	5		
18	1	3	4	6		
19	2	2	4	4		

NOTE: The portions are figured on the basis of nutritional standards.

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