Naval Medical Research Institute
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NMRC 2004-005 December 2004

EVALUATION OF A CARBOHYDRATE-ELECTROLYTE BEVERAGE ON PERFORMANCE DURING MARINE CORPS HOT WEATHER TRAINING EXERCISES

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20060417025

Bureau of Medicine and Surgery
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Washington, DC 20372-5120

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NMRC 2004-005

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-01-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
15 Dec 2004	Technical Report	Jun-Sep 2003

4. TITLE AND SUBTITLE
Evaluation of a Carbohydrate-Elecrolyte Beverage on Performance During Marine Corps Hot Weather Training Exercises

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
602236N

6. AUTHORS
J. Schrot

5d. PROJECT NUMBER
04413

5e. TASK NUMBER
559

5f. WORK UNIT NUMBER
A0256

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Medical Research Center
(Code 00)
503 Robert Grant Ave.
Silver Spring, MD 20910-7500

8. PERFORMING ORGANIZATION REPORT NUMBER
2004-005

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Bureau of Medicine and Surgery
(Med-02)
2300 E. Street, N.W.
Washington, DC 20372-5300

10. SPONSOR/MONITOR'S ACRONYM(S)
BUMED

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
DN241126

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
In response to a request from the Marine Corps System Command (MARCORSYSCOM), Quantico, VA we conducted a proof of concept investigation into the efficacy of a carbohydrate-electrolyte (CHO-E) beverage as a prophylactic against heat stress. The study was conducted to determine if the consumption of a CHO-E drink, as a supplement to water consumption, would sustain the leadership and decision making abilities of junior officers and senior NCOs during field training exercises conducted in hot/humid weather conditions. Subjects were recruited from Marine Corps personnel participating in training courses held at the Marine Corps Base, Quantico, VA during the summer of 2003. The subjects were recruited from a company NROTC students participating in Marine Corps Officer Candidate School (OCS) training, from a company of commissioned junior officers, 2nd and 1st Lieutenants, attending The Basic School (TBS), and from senior enlisted personnel, E-5 and above, attending The Martial Arts Instructor Course (MAIC).

15. SUBJECT TERMS
exercise physiology, heat stress, hydration, electrolyte beverages

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Diana Temple
UNCLASS	UNCLASS	UNCLASS	UNCLASS	19	19B. TELEPHONE NUMBER *(Include area code)* 301.319.7642

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ABSTRACT

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The subjects participated in regularly scheduled training exercises integral to their particular training course. These exercises were conducted as normal training exercises. Participants were graded by a Marine Corps training cadre as they proceeded through each exercise. Copies of those data, identified only by code, were provided to NMRC investigators as the primary datum for analysis.

The study was double-blinded with each subject being randomly assigned to either a CHO-E experimental group or to a placebo control group. Each subject was provided with a 32 ounce drink container prior to the beginning of a training exercise and at 3 hour intervals until training was completed. The subjects had unrestricted access to water throughout training. A urine sample was obtained from each subject before and after each training exercise and

analyzed for hydration status only. A short self-report questionnaire was administered to each subject whenever drinks are distributed.

An evaluation of the data did not reveal any meaningful differences between the CHO-E and placebo subjects on any of the measures obtained in this study. Where statistically significant p values were obtained, the differences were either clinically insignificant as in the case of the urine data, or often revealed the placebo group to be superior, as in the POMS data where the placebo group showed less anxiety and more vigor. However, these differences were small and often 0.5 points or less on a five point scale. The data from the training exercises for the OCS and TBS students showed no difference between the CHO-E and placebo groups. The data obtained from the Martial Arts students were provided as the time each squad required to complete the training course. These data cannot be analyzed statistically as each squad contained both CHO-E and placebo subjects. No individual data scores were obtained during this exercise.

INTRODUCTION

The Naval Medical Research Center (NMRC) was tasked by the United States Marine Corps Systems Command (MARCORSYSCOM), Quantico, VA to conduct a proof-of-concept study. This effort was designed to determine whether the consumption of a carbohydrate-electrolyte (CHO-E) drink during hot/humid weather would sustain the leadership and decision making abilities of Marine Corps personnel during field training exercises. The research was conducted during the summer of 2003 at training facilities located at Marine Corps Base (MCB), Quantico, VA. The subjects were recruited from a company of junior and senior college students participating in Marine Corps Officer Candidate School (OCS) training, from a company of commissioned junior officers, 2nd and 1st Lieutenants attending The Basic School (TBS), and from Non-Commissioned Officers (NCOs) attending The Martial Arts Instructor Course (MAIC).

The subjects participated in regularly scheduled training exercises integral to their particular course. These exercises were conducted with minimal experimental intervention. Participants were graded by a Marine Corps training cadre as they proceeded through each exercise. Copies of those data were provided to the NMRC investigators for analysis. In addition, a urine sample was obtained from each subject within 30 min of beginning and completing each training exercise and analyzed for pH and specific gravity. A subjective measure of affective state, the Profile of Mood States (POMS), was administered approximately 30 min prior to beginning each exercise and at 3 hour intervals thereafter until the exercise was completed (1).

The study was double-blind with each subject randomly assigned to either a CHO-E experimental group or to a placebo (flavored/colored water) control group. Each subject was provided with a 32 ounce drink 30 min prior to beginning the training exercise and an additional

32 oz at subsequent 3 hour intervals until training was completed. Maximum beverage consumption on any day was 128 oz. The subjects had unrestricted access to water throughout training. The data were analyzed for differences between the CHO-E and placebo groups.

Data were collected under the following conditions:

Date-2003	Subject Pool	Number of Subjects	Ambient Temperature	Relative Humidity
06 August	OCS	30	94°F	93%
22 August	TBS	30	96°F	91%
24 September	MAIC	60	83°F	68%

These values represent the prevailing conditions between 1200 and 1400 on each day of testing. The initial beverage distribution, urine collection, and POMS administration took place between approximately 0600 and 0700 for the OCS and MAIC students and between 1100 and 1200 for the TBS students. All data collection was completed by 1800 on testing day.

METHOD

Subjects: One hundred and twenty subjects participated in this study. Thirty subjects each were recruited from an OCS class and a TBS class, and 60 subjects were recruited from an MAIC class. Subjects were recruited without regard to gender, 14 females participated – 10 from OCS and 4 from TBS. Each potential subject pool was briefed on the requirements of the study and volunteers were invited to participate. When more people volunteered than were required, the Principal Investigator (PI) consulted with the training cadre to determine the final subject pool. The final subjects selected from each training course were consented and randomly assigned a subject number. All odd numbered subjects received the CHO-E beverage supplement and all even numbered subjects received the placebo beverage.

Beverage Supplements: The CHO-E beverage supplement and the placebo were obtained by MARCORSYSCOM from the Gatorade Corporation and given to the investigator for distribution to the subjects. Both Gatorade and placebo were obtained in powdered form and mixed with water one hour prior to use following instructions provided by Gatorade. The Gatorade was lemon/lime flavored and colored, and consisted of the commercially available Gatorade formula (Carbohydrate = 5%, Sodium = 5%, Potassium = 1%). The placebo was lemon/lime flavored and colored but it contained an artificial sweetener instead of carbohydrate and was without the electrolytes normally found in Gatorade. The placebo was identical to that used by Gatorade in its in-house research program. The beverages were mixed in identical five gallon insulated containers and distributed to the subjects in unmarked 32 ounce green plastic sports bottles. The beverage supplement was administered in accordance with the guidelines set forth in the most recent Department of Defense (DoD) technical bulletin addressing the control of heat stress (2). The subjects also had unlimited access to water throughout the training exercises.

Data Collection: Approximately 60 min before the beginning of training the investigator met with the subjects at a staging site near the exercise area. Each subject was given a 32 ounce sport bottle and was asked to consume as much fluid as possible during the next 30 min. At the same time they were given a clipboard, pencil and a copy of the 30 item POMS Short Form (Appendix A) with their subject number and instructed to respond to the items "as you feel RIGHT NOW." The POMS forms were collected when the subjects returned the empty drink containers. Approximately 15 min prior to beginning the exercise each subject was asked to provide a urine sample in a standard urine collection device. Portable toilets were available for privacy. When all urine containers were returned they were taken to the Quantico Base Medical

Clinic for the determination of pH and specific gravity (3). The samples were destroyed once the analysis was completed.

The POMS Short Form was administered each time beverages were distributed. This occurred at approximately 3 hour intervals for the duration of the training exercise. A final urine sample and POMS form were collected from each subject within 30 min of their completing the exercise.

Urine data from the TBS subjects was lost due to the extended time required for all subjects to complete the exercise and the ambient temperature (96°F). About 50% of the samples separated out in the heat and could not be analyzed.

The leadership and decision making data were derived from task accuracy measures or expert scorer ratings recorded for each subject as they proceeded through various phases of each training exercise. The scores were provided by the supervising Training Cadre at each school. No individual training scores were obtained from the MAIC students as they were graded by squad and each squad contained both CHO-E and placebo subjects. This data loss was the direct result of misunderstandings between the PI and USMC Senior Training Cadre. The requirements for data collection were transmitted verbally from the PI to the OIC and Senior NCO of the school during a briefing session. The requirements were interpreted such that each squad member would receive the score of the squad, not that each subject had to be evaluated individually.

RESULTS

The results from these tests are presented below. The data are presented as the average (mean) scores for each group with the corresponding standard deviations (SD) in brackets. The results from t-test scores are presented as the probability (p) of rejecting the null hypothesis of no

difference between the groups. Any probability with a value of $p < 0.05$ was considered significant.

Ingestion of the CHO-E supplement did not result in any significant difference in performance compared to the placebo group. The results from the OCS students during the Small Unit Leadership Evaluation 2 (SULE 2) course are presented in Table 1. The results are from the three field problems each subject was required to complete. Under each problem are columns for the two treatment groups, "CHO-E" and "Placebo". The third column under each problem, labeled "p" represents the statistical probability associated with the difference between the mean scores of each group. A value greater than 0.05 is considered to support the hypothesis of **no** difference between the group scores; or to be more precise, there isn't any justification for rejecting the null hypothesis of **no** difference in the scores of the two groups. For each problem and for each group the mean of the scores given to each member of the respective groups by the training cadre is presented. The standard deviation associated with each group score is presented to the left of the mean value (in parentheses). The statistical probability ($_p$) derived by comparing the scores for the two groups for each problem is presented in *italics*.

The maximum possible score that a subject could obtain on the first SULE 2 problem was 50 points, on the second problem 49 points, and on the Reaction Course was 100 points.

An examination of this table reveals that the comparisons on all three problems yielded probability values much greater than 0.05 and therefore suggesting no difference between the groups on any of the problems.

Table 1. Small Unit Leadership Evaluation 2 course (SULE 2) scores.

OCS

	First Problem			Second Problem			Reaction Course		
	CHO-E	Placebo	p	CHO-E	Placebo	p	CHO-E	Placebo	p
Mean (SD)	48.5(1.92)	47.9(3.87)	*0.27*	43.0(4.19)	44.6(4.94)	*0.14*	85.4(4.99)	85.6(6.85)	*0.26*

The data obtained from TBS students during the Land Navigation training exercise are presented in Table 2. The data represent the mean number of "boxes" or locations found, of a total of 5 possible, for each group. The exercise was conducted between 1200 and 1700 hours in a wood and field environment with numerous ravines. There was no significant difference observed between the performance of the CHO-E and Placebo groups. The members of the CHO-E group were able to locate an average of 2.8 of the possible "boxes" while Placebo group members were able to locate an average of 2.93 of their "boxes".

Table 2. Number of "boxes" found (5 possible) during the Land Navigation training exercise.

TBS

	Boxes Found		
	CHO-E	Placebo	p
Mean (SD)	2.80 (1.14)	2.93 (1.62)	0.39

Data obtained from the POMS is presented in Table 3. The short form of the POMS consists of 30 items extracted from the long form of 66 items. The six sub-scales comprising the long form are all equally represented by five items in the short-form. The sub-scales are: 1. Anxiety, 2. Depression/Dejection, 3. Anger/Hostility, 4. Vigor, 5. Fatigue, 6. Confusion. For instance, item 4 "Lively" is from the Vigor sub-scale, while item 7 "Sad" is from the Depression/Dejection sub-scale. A copy of the POMS short-form is included as Appendix B.

The three groups, "OCS", "TBS", and "MAIC" comprising the entire subject sample are presented. The mean score for each group, with its associated standard deviation in (parentheses) and the probability value obtained from the t-test comparison of each treatment group is presented for each sub-scale. Statistically significant differences ($p < 0.05$) are presented in **bold** type face.

Significant differences were found with each subject group. However, the sub-scale differences were not consistent across the groups and more importantly the differences were very minimal. This is exemplified by the scores on the anxiety sub-scale for both TBS and MAIC subjects. The difference between the mean scores for the TBS subjects was 0.31and for the MAIC subjects was 0.14 on a 5.00 point scale. That represents differences of 6 and 3 percent respectively, of the total difference possible on this sub-scale. These differences are interpreted to be meaningless. They, as well as the other differences noted, occurred because of the great similarity or lack of variability observed in the individual scores. The "raw" scores indicate that both groups scored very low on the anxiety sub-scale. This similarity in scores was also observed when other differences were found.

Table 3. POMS results presented by sub-scale factor for OCS, TBS, and MAIC students.* Statistically significant scores in bold type. The direction of the difference can be determined by comparing the average values for each group.

	OCS			TBS			Martial Arts		
Factor	CHO-E	Placebo	p	CHO-E	Placebo	p	CHO-E	Placebo	p
Anxiety									
Mean (SD)	0.68(0.27)	0.61(0.22)	0.058	0.90(0.56)	0.59(0.32)	**0.003**	0.83(0.41)	0.69(0.44)	**0.007**
Depression/ Dejection									
Mean (SD)	0.19(0.16)	0.15(0.13)	0.216	0.43(0.37)	0.26(0.20)	0.110	0.27(0.19)	0.24(0.19)	0.285
Anger/ Hostility									
Mean (SD)	0.26(0.15)	0.23(0.16)	0.134	0.67(0.60)	0.40(0.30)	0.056	0.76(0.29)	0.70(0.27)	0.101
Vigor									
Mean (SD)	1.10(0.55)	1.55(0.64)	**0.011**	1.61(0.71)	1.86(0.74)	**0.018**	1.66(0.45)	1.58(0.53)	0.190
Fatigue									
Mean (SD)	1.45(0.27)	1.26(0.22)	**0.002**	1.34(0.93)	1.19(0.81)	0.370	1.66(0.62)	2.07(0.73)	**0.0002**
Confusion									
Mean (SD)	0.46(0.54)	0.45(0.65)	0.435	0.56(0.73)	0.70(0.74)	**0.047**	0.61(0.66)	0.63(0.69)	0.297

* POMS scores reflect this scale: 0=Not at all 1=A little 2=Moderately 3=Quite a bit 4=Extremely

The data obtained from the urine samples of the OCS and MAIC subjects are presented in Table 4. The urine was analyzed for measures of specific gravity and pH. Samples were taken prior to the start of each training exercise and upon completion of the exercise, and are presented as "AM" and "PM", respectively. Statistically significant differences are presented in **bold** type face.

There were no differences observed between the groups for either measure at either time of day. These data indicate that the groups were approximately equal for hydration status at the beginning and at the end of the training exercises.

Table 4. Urine specific gravity and pH values obtained from OCS and MAIC students before (AM) and after (PM) the completion of training exercises. Statistically significant t scores are presented in bold type. The direction of the difference can be determined by comparing the average values for each group.

	OCS		
Specific Gravity	CHO-E	Placebo	p
AM			
Average (SD)	1.021(0.005)	1.020(0.007)	0.443
PM			
Average (SD)	1.021(0.014)	1.024(0.007)	0.295
pH			
AM			
Average (SD)	5.714(0.452)	5.821(0.486)	0.284
PM			
Average (SD)	5.700(0.600)	5.409(0.358)	0.129
	Martial Arts		
Specific Gravity	CHO-E	Placebo	p
AM			
Average (SD)	1.020(0.005)	1.022(0.006)	0.378
PM			
Average (SD)	1.018(0.007)	1.019(0.002)	0.077
pH			
AM			
Average (SD)	5.885(0.476)	5.804(0.249)	0.245
PM			
Average (SD)	5.520(1.630)	6.000(0.430)	0.064

CONCLUSIONS

Administration of a CHO-E beverage supplement did not alter the decision making ability of the participants in this study when compared to subjects who received placebo. The CHO-E beverage supplement did not change the subjective mood of the subjects as measured by the POMS questionnaire.

Previous research with CHO-E beverage supplements focused primarily on their effects on physical performance measures such as exercise capacity, endurance, cardiac function, metabolism, hydration status, electrolyte balance, thermoregulation, or the palatability (voluntary ingestion rates) of the fluids in subjects exposed to hot environments. (4, 5, 6, 7, 8, 9, 10).

Two previous studies investigated the effect of carbohydrate supplementation on mood (POMS) with equivocal results. A laboratory study (13) found no change in any of the POMS sub-scales after subjects had been exposed to a high carbohydrate diet, a low carbohydrate diet, or a recorded *ad libitum* diet for three days. Another study (4) found decreases in the POMS Confusion subscale and increases in the Vigor subscale following carbohydrate administration in US Army personnel participating in a field study. Neither of these studies was conducted in a hot environment.

A laboratory study (12) conducted at 30° C (86° F) measuring the time to exhaustion at 60% of maximum oxygen consumption while cycling and compared three conditions: 1) no fluid consumption, 2) consumption of a 2% COH-E drink, and 3) consumption of a 15% COH-E drink. The 2% COH-E resulted in the longest mean time to exhaustion (118 min), followed by the 15% COH-E drink (84 min), and lastly the no-drink condition (71 min).

An investigation of fluid and electrolyte loss was conducted with US Army personnel wearing temperate battle dress uniforms (BDU) during sustained exercise on a treadmill over a

six hour period (28.0 km – total distance) at an ambient temperature of 30° C (86° F) (11). The study reported electrolyte losses which exceeded normal daily intake during the six hour test period. Another study (5) evaluated the effectiveness of a CHO-E beverage, compared to placebo or water, on military tasks such as an uphill run, rock climbing, and marksmanship, repeated during a three day field exercise with ambient temperatures of approximately 30° C (86° F). Averaged across the three days, the results indicated no difference between the treatment groups. However, when performance on individual days was examined it was found that the soldiers receiving the CHO-E supplement were better able to sustain both uphill run and marksmanship performance during Day 3 than were the other soldiers.

The subjects who participated in this study were a self-selected, highly motivated, homogenous group of young men and women. The OCS Candidates were primarily college seniors who had spent three years participating in Marine Corps ROTC courses preparing to become Marine Corps Officers. Their performance during the summer training program would largely determine whether they would be selected to become Marine Corps Officers upon graduating from college. The participants in TBS training were men and women who had been selected as Marine Corps Officers and their performance during the six months of training would determine retention and assignment to an operational billet. The participants in the MAIC were senior enlisted personnel who had reenlisted in the Marine Corps at least once and who had been selected by their respective line commands as outstanding Marines with the dedication and motivation to become Martial Arts Instructors.

The homogeneity of the subject pool is reflected in the data. The measures used resulted in very little variability, either within the subjects of each group or between the two groups. The OCS candidates scored an average of 48.5 points for CHO-E group and an average of 47.9 points

for the placebo group out of a possible 50 points on the first problem. The standard deviations for the respective groups were 1.14 and 1.62. This means that approximately 70% of the subjects in the CHO-E group obtained scores of between 46.8 and 49.0 points. The comparable range of scores for 70% of the Placebo group fell between 46.3 and 49.5 points. The consistently high scores and very limited variability prevented any potential beneficial effect of the CHO-E supplement from manifesting in the results. Similar findings can be seen in results of the second OCS problem, the OCS Reaction Course, and in the POMS data.

The Land Navigation data obtained from the students in TBS was limited by the nature of the problem. The students could only achieve a maximum score of 5, a limit imposed by the number of boxes or locations available to be found. Given that the Placebo group found an average of 2.9 boxes the CHO-E group would have had to find an AVERAGE of 3.8 boxes for the difference between the groups to achieve statistical significance. That is an unrealistic expectation given the comparable skill level of the entire student class and the discrete nature of the scoring system. A student cannot find 3.5 boxes, boxes can only be found in discrete numbers between 0 and 5. To achieve a group average of 3.8 the majority of the group members would have had to find 4 or 5 boxes, in other words to score well above their skill level. It is unrealistic to expect a relatively subtle intervention such as the acute introduction of a beverage supplement to provide that magnitude of an advantage.

In general, the results of this study are inconclusive with respect to the efficacy of CHO-E beverage supplements to sustain decision making or cognitive function in hot/humid environments. The absence of any differences between the groups could have resulted from a number of factors including the nature and duration of the tasks performed, the homogeneity and motivational level of the subject populations, or the sensitivity of the measuring instruments.

Future studies should identify relevant skills that have been demonstrated to deteriorate as a result of heat exposure, either as result of prolonged exposure, temperature gradients, or a combination of both. Once the relevant skills and environmental conditions have been established, evaluating the efficacy of an intervention designed to prevent the change becomes simplified.

ACKNOWLEDGEMENTS

This work was supported by the Marine Corps Systems Command, Work Unit No. 602236N.04413.559.A0256. The opinions and assertions contained herein are the private ones of the author and are not to be construed as official or reflecting the views of the Navy Department or the naval service at large.

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Appendix A: Measurement of temperature and humidity conditions at Marine Corps Base, Quantico, VA

a. Temperature and Humidity:

Wet Bulb Globe Temperature Index (WBGTI) devices are located in the training areas and are monitored and recorded on the hour between 0700 and 1900 by Marine Corps Instructors. This information is used to determine Training Condition Heat Stress Level as follows:

WBGTI	Condition	Flag
80-84.9°F	Alpha	Green
85-87.9°F	Bravo	Yellow
88-89.9°F	Charlie	Red
90°F +	Delta	Black

A more detailed exposition of these conditions can be found in MCBO (Marine Corps Base Order) 6200.1 W/CH1 of 29 Feb 00, MCB, Quantico, VA.

The temperature and humidity data reported here were obtained from the data recorded by the Training Cadre during the course of each exercise.

Appendix B: Profile of Mood States – Short Form

SEX: Male (M) Female (F) Identification No. _____

Below is a list of words that describe feelings people have. Please read each one carefully. Then fill in ONE circle under the answer to the right which best describes HOW YOU FEEL RIGHT NOW INCLUDING TODAY.

The numbers refer to these phrases.

(0) = Not at all
(1) = A little
(2) = Moderately
(3) = Quite a bit
(4) = Extremely

	Not at all	A little	Moderately	Quite a bit	Extremely
1. Tense	0	1	2	3	4
2. Angry	0	1	2	3	4
3. Worn out	0	1	2	3	4
4. Lively	0	1	2	3	4
5. Confused	0	1	2	3	4
6. Shaky	0	1	2	3	4
7. Sad	0	1	2	3	4
8. Active	0	1	2	3	4
9. Grouchy	0	1	2	3	4
10. Energetic	0	1	2	3	4
11. Unworthy	0	1	2	3	4
12. Uneasy	0	1	2	3	4
13. Fatigued	0	1	2	3	4
14. Annoyed	0	1	2	3	4
15. Discouraged	0	1	2	3	4
16. Nervous	0	1	2	3	4
17. Lonely	0	1	2	3	4
18. Muddled	0	1	2	3	4
19. Exhausted	0	1	2	3	4
20. Anxious	0	1	2	3	4
21. Gloomy	0	1	2	3	4
22. Sluggish	0	1	2	3	4
23. Weary	0	1	2	3	4
24. Bewildered	0	1	2	3	4
25. Furious	0	1	2	3	4
26. Efficient	0	1	2	3	4
27. Full of pep	0	1	2	3	4
28. Bad-tempered	0	1	2	3	4
29. Forgetful	0	1	2	3	4
30. Vigorous	0	1	2	3	4

MAKE SURE YOU HAVE ANSWERED EVERY ITEM.

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SHORT FORM

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