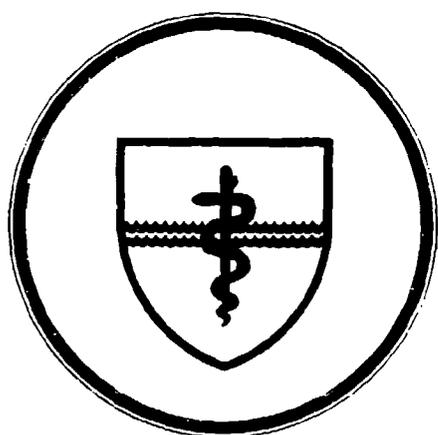


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NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

SUBMARINE BASE, GROTON, CONN.



REPORT NO. 1053

PHYSICAL ACTIVITY ABOARD NUCLEAR SUBMARINES
AS MEASURED BY PEDOMETRY

by

Kenneth R. Bondl and James H. Dougherty, Jr.

Naval Medical Research and Development Command
Research Work Unit MF58.524.003-0004

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Naval Submarine Medical Research Laboratory

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SUMMARY PAGE

PROBLEM

The length of sea duty time in a submarine and the inability to exercise significantly because of the confines of the environment led us to speculate that physical deconditioning is decreased in submarines as a result of decreased activity. We sought to determine the magnitude of this decreased physical activity, so that recommendations could be made on the amount of physical activity one should engage in to maintain physical fitness during long submarine patrols.

FINDINGS

Activity levels of 44 submariners were monitored before and during a fleet ballistic missile submarine patrol. These levels were determined by use of a pedometer worn on the hip. Readings were obtained daily and recorded in a log as "miles" walked. Through extensive preliminary testing it was determined that the "miles" unit was useless, due to variability in the sensitivity of the pedometer pedulum movements and the inability to determine a meaningful "stride length". Results for any combination of pedometer/user were, however, repeatable. For lack of a better term, results are reported in "miles per day" and are as follows: Control = 2.11 ± 0.32 and Underway = 1.01 ± 0.27 ($P < .05$, Student T). This reduction of more than 50% in activity level may in part be responsible for the physical deconditioning observed during the course of a 40-70 day submergence period.

APPLICATIONS

The significant drop in activity levels while underway indicates the possible need for a physical fitness program aboard underway submarines.

ADMINISTRATIVE INFORMATION

This work was conducted as part of the Naval Medical Research and Development Command Work Unit MF58.524.003-004 Enhancement of Physical and Mental Performance in Submarines Through the Promotion of Increased Fitness and Health." It was submitted for review on 25 Mar 1985, approved for publication on 23 May 1985, and designated as NSMRL Report No. 1053.

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ABSTRACT

Activity levels of 44 submariners were monitored before and during a fleet ballistic missile submarine patrol. These levels were determined by use of a pedometer worn on the hip. Readings were obtained daily and recorded in a log as "miles" walked. Through extensive preliminary testing it was determined that the "miles" unit was useless, due to variability in the sensitivity of the pedometer pendulum movements and the inability to determine a meaningful "stride length". Results for any combination of pedometer/user were, however, repeatable. For lack of a better term, results are reported in "miles per day" and are as follows: Control = 2.11 ± 0.32 and Underway = 1.01 ± 0.27 ($P < .05$, Student T). This reduction of more than 50% in activity level may in part be responsible for the physical deconditioning observed during the course of a 40-70 day submergence period.

PHYSICAL ACTIVITY ABOARD NUCLEAR SUBMARINES AS MEASURED BY PEDOMETRY

K. R. BONDI AND J. H. DOUGHERTY

Sea duty time for a Fleet Ballistic Missile submarine, which is spent mostly submerged, is 70 days. This length of time, coupled with the fact that the submarine has very little available room in which crew members may exercise, led us to speculate that physical conditioning is decreased as a result of a low level of activity. While the degree of physical activity can be determined precisely in the laboratory by measuring oxygen uptake, this obviously could not be done on a large group of submariners underway. We therefore chose to monitor activity levels with the pedometer, recognizing the limits of such a device, but also realizing that no other method was suitable.

METHODS

Subjects

Volunteers were recruited from among the male crew members of three fleet ballistic type submarines (designated B, J, and K) who ranged in age from 17 to 39 years. They signed consent forms and were informed that this study was approved by the Laboratory's Committee for the Protection of Human Subjects.

Prediver

New Haven pedometers (Pedometer Corporation, Newark, New Jersey) were used for all data collection. Subjects were instructed to clip the pedometer to their belt on the right or left hip. Pre-patrol (control) measurements were obtained for periods ranging from 31 to 46 days. While on the submarine, subjects were instructed to wear the pedometer at all times except when taking showers or sleeping and to record the "mileage" every 24 hours. Extensive testing of the pedometers at our laboratory (see Appendix) consisting of walking a measured mile and shaking the pedometers so as to register a quantitative reading per number of pendulum swings, showed that the error between two readings which should have registered 1 mile travelled, was less than 3%. Since the average recorded mileage was between 1 and 2 "miles" per day (see results), the error contributed by the pedometer when comparing control versus experimental results was minimal.

RESULTS

Table 1 summarizes the results obtained in this study. Pedometer mileage was clearly and significantly ($p < .05$) reduced to 1.01 during shipboard underway periods versus 2.11 for land-based periods. While the greatest reduction of 1.76 miles per day was seen in submarine K, its subject group contained only 3 volunteers. The smallest reduction of 0.63 miles per day for submarine J was still significant at the 5% level.

DISCUSSION

The data presented here is given in units of "miles per day". While the pedometer in fact reads "miles" on its indicator face, it is only under the specific conditions of walking on a flat surface and knowing one's stride length that a reasonable estimate of distance travelled is obtained. In an effort to compare the "activity levels" for two different time periods, as

was the object of this study, mileage indication has little, if any, meaning. A more appropriate term would have been "activity units", since the pedometer registers almost all significant movements. Each pedometer used in this study was set at a "standard" pace length, regardless of the leg length or stride of the individual, removing the data further from the connotation of "distance travelled".

Each submariner served as his own control, the same pedometer being worn during the control or shore based activity as that which was worn during the underway or shipboard (patrol) period. The activity levels while underway were reduced by 50%. While these data corroborate the long-held notion and reasonable estimation that activity levels are reduced in the confines of the underway submarine, they do not estimate the amount of aerobic and anaerobic deconditioning that occurs during these periods. Previous work done on American (1,2,3) and English (4) submarines has shown a significant aerobic deconditioning upon returning from an extended (40-70 days) at sea period. It is reasonable to conclude therefore that the measured decrease in activity levels during underway periods leads to physical deconditioning.

Does a decrease in activity leading to decreased physical conditioning affect the long- or short-term health of the submariner? Are the operational tasks of the submarine carried out at less than maximal efficiency as the result of decreased physical and mental performance? It is not the intention of this communication to extoll the beneficial health aspects of physical fitness, but it is generally accepted by the lay public and the medical and scientific communities that both short term and long term health is enhanced by the maintenance of a high level of physical fitness. Unfortunately, a positive link between increased physical fitness and enhanced mental performance has not been definitively demonstrated. It is, however, the position of this laboratory, having thoroughly reviewed the literature in this area, that increased physical fitness will produce a more vigilant and productive worker, with the converse likely also to be true (Bennett & Bondi, 5). It is concluded therefore that submariners will perform, both physically and mentally, in a more optimal fashion if their fitness levels can be maintained, while underway, by an increased level of activity.

TABLE 1
PEDOMETER READINGS IN "MILES PER DAY" FOR A CONTROL PERIOD (LAND BASED)
VERSUS AN UNDERWAY PERIOD (SHIP BASED)

| Submarine | Underway Period-days | No. of Subjects | PEDOMETER READINGS | | |
|-----------|-------------------------|--------------------|--------------------|------------|---------------------|
| | | | Control | Underway** | P-Value (t-test) |
| B | 37 | 20 | 2.01+1.13 | 1.08+0.60 | <.01 |
| J | 68 | 21 | 1.86+1.54 | 1.23+0.85 | <.05 |
| K | 68 | 3 | 2.47+0.16 | 0.71+0.13 | <.01 |
| | | Mean ±SD | 2.11±0.32 | 1.01±0.27 | <.05 |

* Control period for B was obtained pre-patrol while stationed aboard a submarine tender; for J was obtained during a pre-patrol period ashore, and for K was obtained during a post-patrol period ashore. Collection periods ranged from 31 to 46 days.

** Data collection times for the underway (patrol) periods were 34, 65, and 64 days for B, J, and K, respectively.

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APPENDIX

One sample each of four different brands of pedometers ranging in cost from \$12-20 were tested. Since this was not an extensive test, we do not feel it is appropriate to name the three brands not selected for use. The brand we used (New Haven Pedometer, made by Pedometer Corporation, 96 Monroe Street, Newark, New Jersey 07105) was chosen because it had fewer deficiencies than the others. The following calibrations were performed.

First, ten men ranging in height (and presumably stride length) from 63 to 76 inches walked a football field. They covered the 100 yard length 17.6 times (1 mile) while an observer counted their steps. An average stride length was then computed and a stride adjustment inside the pedometer was made for each individual. These same subjects with the pedometer set at their determined stride length, then walked an indoor course that took 31-50 minutes to complete and was laid out, through preliminary walks, so that the pedometer registered about a "mile walked". In an attempt to simulate an office worker's activity and to some extent a submariner's activity this "mile walk" was interspersed with significant periods of sitting, standing, and walking up and down stairs. The mileage results for this traversed course were very interesting. We purposely chose tall and short men so that the stride length varied widely. The results were as follows:

| | | | | | | | |
|---------------------|-------|-------|-------|-------|-------|-------|-------|
| STRIDE LENGTH | 34.6" | 28.6" | 30.5" | 33.3" | 34.8" | 32.1" | 33.8" |
| HEIGHT(inches) | 63 | 63 | 65 | 72 | 74 | 76 | 76 |
| "Mileage Recorded"* | 2.00 | 1.23 | 0.80 | 0.68 | 0.60 | 0.65 | 0.45 |

* Indoor course after setting for stride length on football field.

The relationship of subject height to "mileage" recorded (for the same course!) is striking. Even though the subjects traversed an exactly similar course, the pedometers worn by the taller subjects indicated less mileage walked than the shorter subjects. Whether it is the tall person's lumbering gait that caused a lower reading or the bouncy activity of the shorter subjects that caused an increased movement of the pedometer, is speculative. The correlation of stride length (and thus the sensitivity of the pedometer) to mileage recorded is not that good, although it seems that the greater the stride length the less mileage recorded (with the obvious exception of the longest stride length subject).

A shaking test was performed on each pedometer. The back was opened and the stride length set at the maximum of 40 inches. Tape was placed on the resetting screw to keep it from accidentally turning. The units were then placed in the manufacturer's box in an upright position (as worn on the belt). Twelve of these individual boxes were placed in a larger box, and

this larger box was then moved up and down manually (with an audible "clunk" heard as the conglomerate of pendulums moved up and down in unison) for 792 times. This should have given a reading of 0.5 miles with a 40-inch stride setting. It was then realized that the sensitivity of the 40-inch stride setting was too great and could have given random, double rebounds. The sensitivity of the pedometer was decreased by selecting a 20 inch stride. Shaking 792 times should have moved the pointer 0.25 miles. Two "shaking" and recording tests were performed. If the two readings for individual pedometers from the shaking tests were within 0.06 "miles" of each other, they were averaged. If not, a third "shaking test" was performed. If there were not two values within 0.06 "mile" of each other the pedometer was considered unacceptable.

The absolute reading of the acceptable pedometers varied from 0.15 to 0.60 miles. The average variation between two shaking tests was 0.0247 miles (n = 44). A reading error, which we determined to be 0.005 miles would be a very small percentage of any daily mileage reading of 2.5 miles.

From the football field (exact stride length determination) data and the "same course" data, we determined that the setting of stride length for each person would not give any more reliable data than if a common stride length was selected and set for each subject. From the shaking data we determined that a small stride length setting (least sensitive) on the pedometer would produce fewer falsely high readings due to double bounces of the pedometer's pendulum. Using the above criteria and reasoning we felt that the data collected for any given person/pedometer combination for any one period of time is directly comparable to data collected for a different period of time.

The following additional observations and conclusions were made.

- 1) The pedometer should be placed laterally on right or left hip; not near the midline.
- 2) Approximately 12% of pedometers are defective when brand new. That is, the pointer does not move at all or indicates an absurdly higher reading (i.e., 5.0 instead of 0.25 miles) on the "shaking test".
- 3) Some belt-holders come off the pedometer; this can generally be repaired.
- 4) Clip should be placed under belt with loose end on outside. The instrument is less likely to fall off the belt this way.
- 5) Pedometers should be set to a 20" stride length for pre/post comparative results (their lowest sensitivity setting).
- 6) Pedometers should be "calibrated" with the "shaking test" before use and after a study to make sure they have not shifted greatly or become completely defective.
- 7) Replacing a loose spring on a defective pedometer will sometimes repair it.

If set up as described above, the pedometer will not measure miles or distance very accurately except while walking on a flat area with uniform stride length. Running, climbing stairs, etc. will cause a movement of the pendulum with a slight movement of the ratchet drive system. In these cases, an "activity unit" instead of miles is being measured. A 1-foot high stair, for example, requires more energy than a horizontal forward step 2 1/2 feet long, yet the pedometer registers the same. Pedometers do allow the collection of crude data on activity on large numbers of subjects for periods of an hour to a few months at a relatively low cost. The much higher cost of accelerometers and other instruments would often preclude their use on a large number of subjects.

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